BIOLOGICAL CHARACTERISTICS OF NORTHER SHRIMP (PANDALUS BOREALIS KRØYER) IN AREAS OFF LABRADOR

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BIOLOGICAL CHARACTERISTICS OF NORTHERN SHRIMP (*Pandalus borealis* Krøyer) IN AREAS OFF LABRADOR

by

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ABSTRACT

Northern shrimp (Pandalus borealis) occurring in the Hopedale, Cartwright and Hawke channels off the Labrador coast were examined. Based on results from research surveys from 1979-81, distribution was concentrated in water between 2 and 4°C in depths greater than 300 m. Changes in distribution and abundance were also observed between years. Density and abundance appeared to have decreased in the Hopedale and Hawke Channels during this period, while in the Cartwright Channel only changes in density distribution were noted. Variations in catch rate over a 24 hour period were related to vertical migration of shrimp and the effects of tidal currents on shrimp distribution and performance of sampling gear were discussed. Biological characteristics such as sex and maturity, weight-length relationships, fecundity and food and feeding were examined. Generally, shrimp in these areas appeared to be obligatory protandric hermaphrodites. Sex change occurred over a range of sizes which may vary with changing environmental parameters or fishing mortality directed at the larger female shrimp. Weight-length relationships were similar to those reported for conspecifics in other areas of the northern hemisphere. Fecundity of shrimp off Labrador appeared to be less than that reported in warmer regions but greater than that observed in colder water populations. Food and feeding patterns were similar to those demonstrated for other northern shrimp stocks. Statistical and descriptive comparisons of the above characteristics indicated differences between channels which, in some cases, may represent different stock characteristics. Infection of shrimp

eggs by a tentatively identified dinoflagellate represents potential for egg mortality and spawning failure. Necrosis of striated muscle of shrimp was associated with infections by a microsporidian, possibly of the genus Thelohania.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Shrimp of the family Pandalidae Haworth, 1825, are worldwide in distribution and comprise eighteen recognized genera (Butler 1980). Several genera are commercially important and support fisheries in colder waters of both the northern and southern hemispheres. Their value, in this regard, is exceeded only by the tropical and subtropical Penaeidae (Holthuis 1980).

The genus Pandalus Leach, 1814, has been recognized as the component of major economic importance in both the north Atlantic and Pacific Oceans (Longhurst 1970; Scrivener and Butler 1971). Pandalus borealis Krøyer, 1838 (known in Canada as northern shrimp, pink shrimp, crevette nordique and kingnouk), is considered the primary shrimp resource in the northwest Atlantic (Longhurst 1970). In recent years landings of the species in this area have been the highest for all marine crustacea [Northwest Atlantic Fisheries Organization (NAFO) 1981]. Pandalus borealis also occurs in the Pacific, where it ranks third in importance after P. jordani and P. platyceros off the British Columbian coast (Butler 1980) and is the main species in fisheries off Japan (Ito 1976) and the eastern U.S.S.R. (Kitano and Yorita 1978).

The general distribution of P. borealis has been described as circumboreal or circumpolar (Rathbun 1904; Allen 1959; Haynes and Wigley 1969). In the northwest Atlantic it occurs on George's Bank (north of 41°N), in the Gulf of Maine and in depressions on the Scotian Shelf. Farther offshore it is found on the Grand Banks, Flemish Cap and northeast Newfoundland Shelf. Fisheries have existed since the mid 1960's in the Gulf of St. Lawrence (Couture

and Trudel 1968) and concentrations have been located in Newfoundland bays and along the southwest coast of the Island. In recent years, commercial concentrations have been found in deep water channels on the Labrador Shelf and the species has even been reported from Lake Melville. Continuing northwards it is found in Hudson Strait, Ungava Bay and on the west side of Davis Strait off Baffin Island. Concentrations have been known for many years off west Greenland and a large offshore fishery has developed in the last decade.

Distribution is continuous through east Greenland and the northeast Atlantic including the Norwegian, Barents and North seas. In the Pacific the species[1] occurs in Japanese waters (as far south as 35°30'N), on both sides of the Kamchatka Peninsula and in the Bering Sea, then continues on the western North American coast from the Aleutian Islands as far south as the Columbia River. Details of distribution represent a composite of information provided by Allen (1959), Haynes and Wigley (1969), Butler (1971), Sandeman (1971), Squires (1970), Ito (1976), Fontaine (1979), Smaldon (1979), and Holthuis (1980).

Northern shrimp are usually found on soft muddy substrate (Butler 1971) but recent underwater photographs taken over the Greenland offshore shrimp grounds suggest that they occur on more coarse substrate than previously believed (Kanneworff pers. comm.). Allen (1959) states that temperature, salinity, substrate and possibly depth are factors limiting its distribution. In fact, all or any of these may act singly or collectively in affecting distribution. A recent study in the Davis Strait (Anonymous 1978) statistically analyzed these environmental factors. The results

[1]Holthuis (1980) reported that the taxonomic status of the Pacific form has not been elucidated and may be a subspecies Pandalus borealis eous Makarov, 1935.

indicated depth as the single most important element influencing levels of shrimp catches in that area.

Although the interaction of environmental factors is unclear and likely variable, a preferred and relatively cold temperature range has been identified. The species favours temperatures between 3° and 8°C (Rasmussen 1965) but adults have been encountered in waters as low as -1.68°C and as high as 11.13°C (Allen 1959). Salinities encountered in areas where larvae and/or adults are found range between 25.9 and 35.7 °/₀₀ (Butler 1971).

Depths where favourable conditions exist for these shrimp, cover a broad range. They occur in shallow boreal waters where temperatures do not exceed the limits of toleration and in considerably deeper waters where temperatures are relatively constant throughout the year, unlike the upper water layers where temperature may fluctuate substantially between seasons. Butler (1971), in reviewing literature on distribution, interpreted a range of 9 to 1380 m with 'fishable' concentrations normally occurring between 54 and 400 m. Parsons et al. (1980) found 'fishable' concentrations off Labrador in depths greater than 500 m.

Allen (1959) stated that evidence for diel vertical migration of pink shrimp has been documented since the early 1900's. In more recent years these patterns have been studied to determine times of optimum density on or near the bottom and the characteristics of the vertical migration (Apollonio and Dunton 1969, Barr 1970, Berenboim et al. 1976, Horsted 1978a, Carlsson et al. 1978, Smidt 1978, Anonymous 1978, Parsons 1979, Parsons et al. 1980). This behaviour is apparently associated with feeding since various

investigators have noted pelagic crustacea as an important component in the diet (Horsted and Smidt 1956, Barr 1970, Squires 1970, Butler 1980).

Protandric hermaphroditism was first described in P. borealis by Berkeley (1930). The animal first functions sexually as a male, then undergoes a transitional stage after which it spends the rest of its life as a female. Most malacostracans are gonochoristic (dioecious) with genetically determined sex but several decapods (most notably the pandalids) and two families of isopods (the Cymothoidea and the Cryptoniscidae) are functionally protandric and possess ovotestes (Charniaux-Cotton 1975). In Pandalus the ovotestes have two distinct germinal areas, the axial part giving rise to the oogonia and the outer layers producing spermatogonia.

The timing of sex change is variable between and within different areas and in some cases the male condition is eliminated altogether (Butler 1971). Temperature appears to be the most accepted explanation governing this process with northern-most populations exhibiting slower growth and maturation and increased longevity (Horsted and Smidt 1956, Squires 1968, Apollonio and Dunton 1969, Haynes and Wigley 1969). However, population density and the male to female ratio have also been interpreted to affect the timing of sex change (Charnov 1981). The male phase lasts from 2 1/2 to 5 1/2 years depending on the area, with females, in more northern populations, living up to eight years or longer (Allen 1959, Haynes and Wigley 1969, Butler 1971). Squires (1968, 1970) suggested that in very cold water populations around Newfoundland some males might never change sex and some females probably spawn biennially. The egg-bearing

or ovigerous period is also variable with a shorter season occurring in warmer waters. Shrimp off coastal British Columbia carry eggs only two or three months while females of the same species at Spitsbergen are ovigerous for over half a year (Haynes and Wigley 1969).

Information on the detailed distribution of shrimp off Labrador had been lacking up to the early 1970's. Exploratory, research and some commercial fishing began in 1975 and by 1977 a commercial fishery directed at the northern shrimp was initiated (Sandeman 1978). In late 1977 a Soviet research cruise studied shrimp distribution using underwater photography (Serebrov 1978). From 1978 to 1981 three areas have been regulated by total allowable catch based on abundance indices derived from research surveys and commercial data (Sandeman 1978, Axelsen et al. 1979, Parsons et al. 1979, 1980, 1981a). These areas have become known as the Hopedale, Cartwright and Hawke channels (Fig. 1). Grounds off the Labrador coast north of 57°N where shrimp are found are less well-defined due to a paucity of commercial and research data. Limited information on shrimp distribution in this area was given by Veitch et al. (1980).

Based on information from the above references, the general distribution off Labrador can be outlined. Shrimp occur in the three channels previously mentioned from depths of 165 m to 600 m or more. Most fishing activity is concentrated between 250 and 500 m. Temperatures encountered in these regions vary between 2.0 and 4.0°C and are similar to those found on the commercial shrimp grounds in the Davis Strait (Carlsson and Smidt 1978).

A limited data base for the commercial shrimp fishery in the Labrador Channels restricts stock assessment techniques to a rudimentary

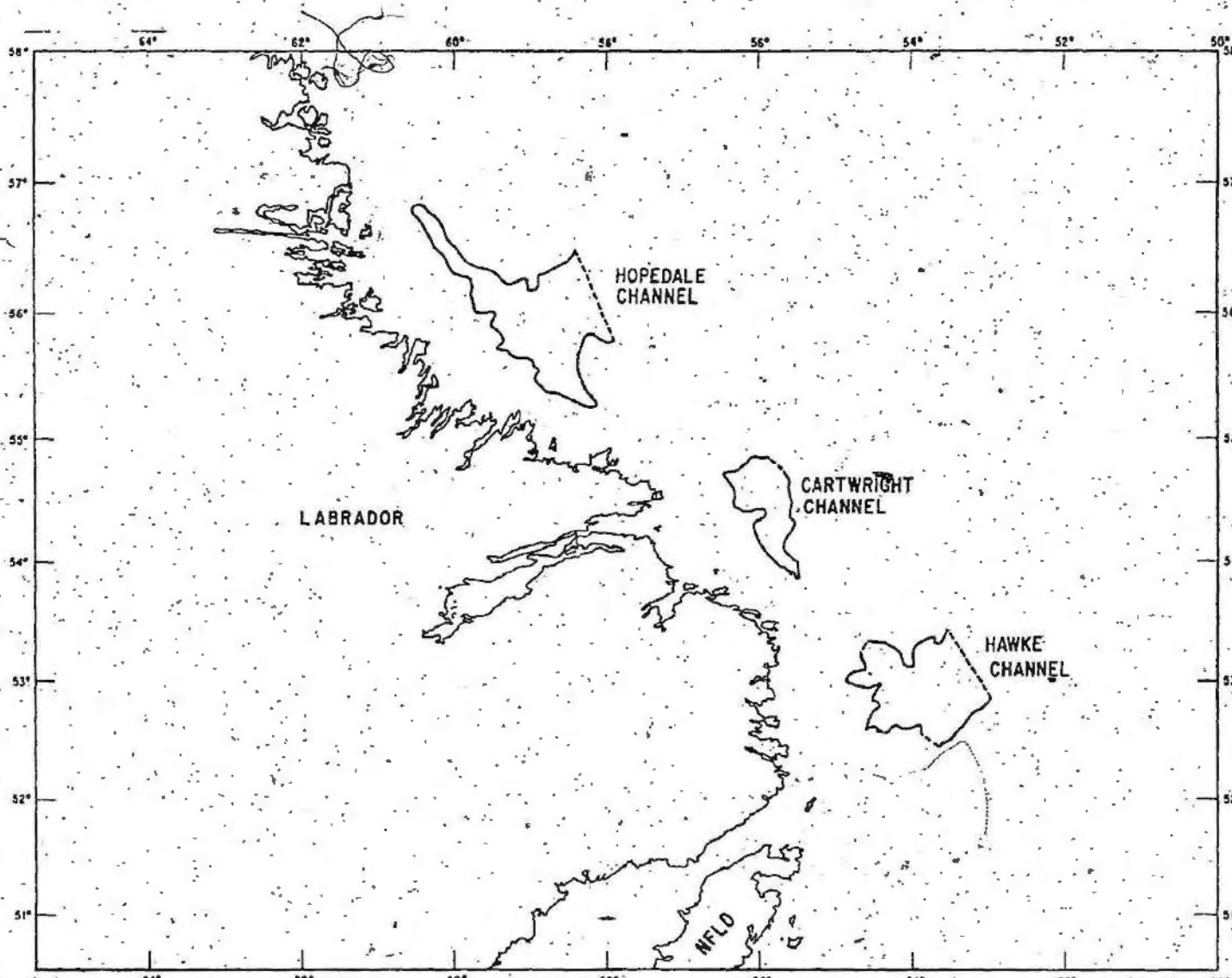


Fig.1. Areas of shrimp (Pandalus borealis) concentration on the Labrador Shelf defined by the 200 m. contour.

level. Knowledge of the biology of the species in these areas is also lacking. Consequently, estimation of potential yield from these resources using even the most general of fisheries models often requires input of vital parameters (eg. mortality, weight/length relationships) which have been derived for other stocks.

The present study was designed to elucidate some of the biological characteristics of shrimp in these areas, to determine what similarities and/or differences exist between areas of concentration and to consider the results in relation to fisheries management. Such biological background is essential for the application and interpretation of the various models used in resource assessment. These assessments provide a basis for the multidisciplinary management scheme which has been applied to the northern shrimp fishery in recent years and in which industry plays an active role.

Research cruises to the Labrador offshore area from 1979 to 1981 were designed to determine the details of shrimp distribution in the Hopedale, Cartwright, and Hawke Channels. The data obtained permit a general description of shrimp distribution in each channel and a comparison between years as well. Repetitive fishing in specific areas in 1980 and 1981 was carried out to determine patterns of diel variability in catch rates. Stratification of areas of shrimp concentration by depth was employed to determine zones of maximum density and investigate possible changes in size with depth.

Sampling of the shrimp catches from each fishing set included observation of the details of sex and maturity from each area of concentration. The data enabled comparisons of these characters to

be made between and within areas. The possibility of changes in sex and maturity due to fishing is also discussed.

Samples were obtained for each channel to determine weight-length and fecundity-length relationships. These data are compared statistically for possible differences between areas and years and within years. A descriptive comparison of these relationships is made with those of northern shrimp populations in other parts of the world.

Food and feeding of the northern shrimp in various areas have been associated with both the benthic and pelagic zones. A general description of food and feeding for shrimp in the Labrador channels is provided with some comparisons between areas and sexual condition.

Preliminary investigations are made of two parasitic infections of northern shrimp. One infects the eggs carried by the female and represents a potential for reduced fecundity and possibly recruitment failure. A similar condition has been described in shrimp eggs from the Gulf of Maine (Stickney 1978). The other extensively infects the striated muscle of the shrimp, giving the muscle an opaque or cooked appearance. Although infection rates appear to be low, the condition represents a potential for increased mortality and possibly a quality control problem for the industry, especially if epidemics occur. A similar condition for Pandalus jordani in the Pacific has been related to infection by a microsporidian (Johnston et al. 1978).

METHODS AND MATERIALS

Distribution

Data on the distribution of shrimp off coastal Labrador were collected during July research trawl surveys of the M.V. ZAGREB in 1979 and GADUS ATLANTICA in 1980 and 1981. Both vessels used a Sputnik 1600 shrimp trawl (Appendix I) lined in the last 6 m of cod end with 13 mm mesh[2]. Mesh size usually ranged from around 80 mm in the wings to 42 mm in the codend. The headline of the trawl was 43 m and the footrope 51 m. The estimated horizontal opening of the trawl between wingtips was approximately 22 m (Carrothers pers. comm.).

During each cruise, standard survey lines were fished in each channel (Fig. 2) at approximately 40-50 m depth intervals. The standard trawling time (tow) was 30 minutes duration and the abundance index was given in terms of catch (kg) per standard tow. Vessel speed during trawling was estimated at 3.0 knots and warp (wire) length to depth ratio was approximately 3 to 1. Bottom temperatures obtained by an expendable bathythermograph (XBT) for each fishing set were averaged for each depth stratum. The variability in temperature at similar depths in these areas is usually small and not important in this study. In fact, temperatures at these depths may be reasonably constant at different times of the year (Parsons, unpublished).

The most commonly employed measurement for shrimp in general and P. borealis in particular is the carapace length. The carapace length is represented by the distance between the most posterior

[2]The international Commisson for the Northwest Atlantic Fisheries (ICNAF) Handbook (1969) states: "Mesh sizes are measured by a fleet wedge-shaped gauge having a taper of 2 cm in 8 cm and a thickness of 2.3 cm, inserted into the meshes under a pressure or pull of 5 kilograms.

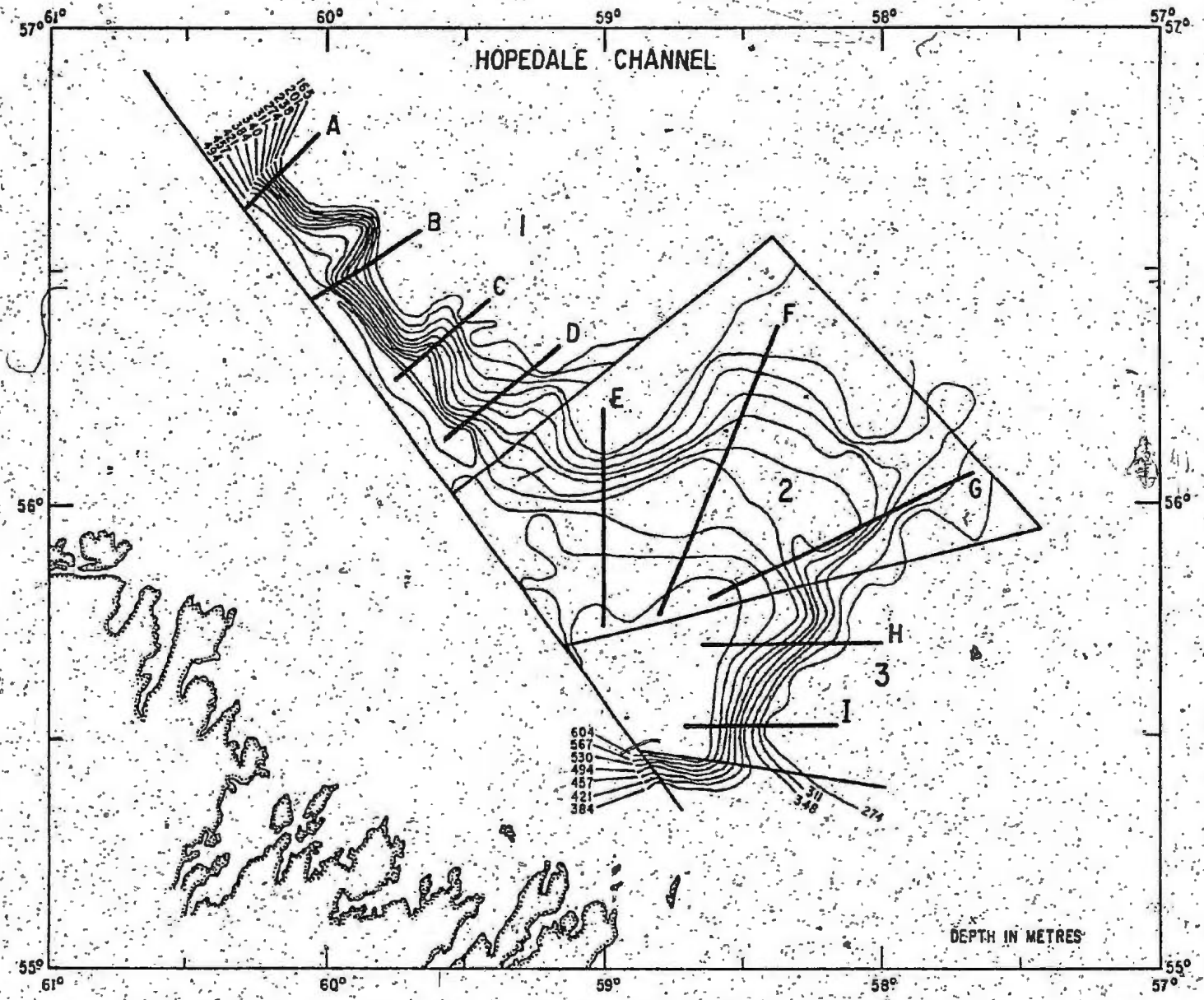


Fig. 2 a) Interpretation of bathymetry and survey lines (A-I) in the Hopedale Channel.

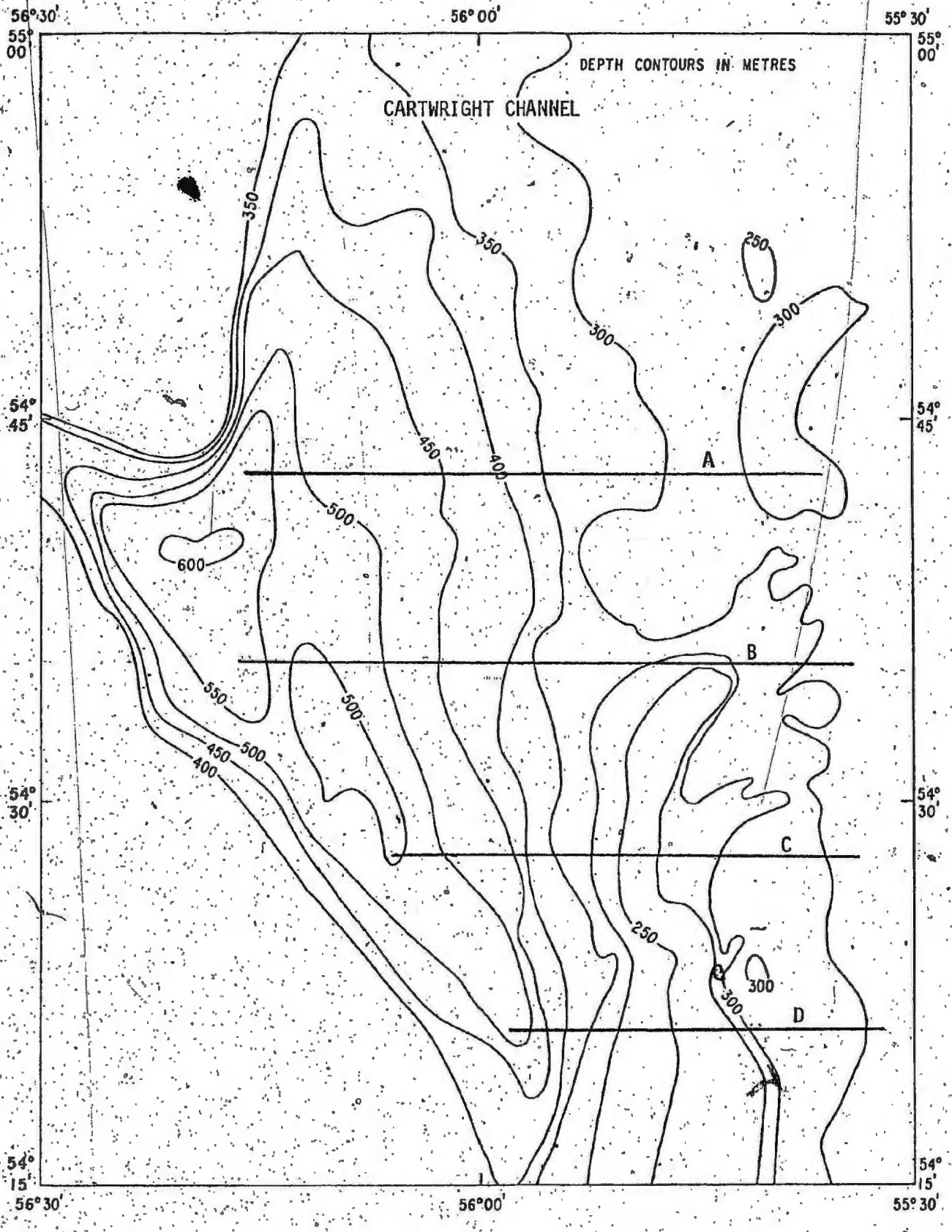


Fig.2 b) Bathymetry and survey lines (A-D) in the Cartwright Channel.

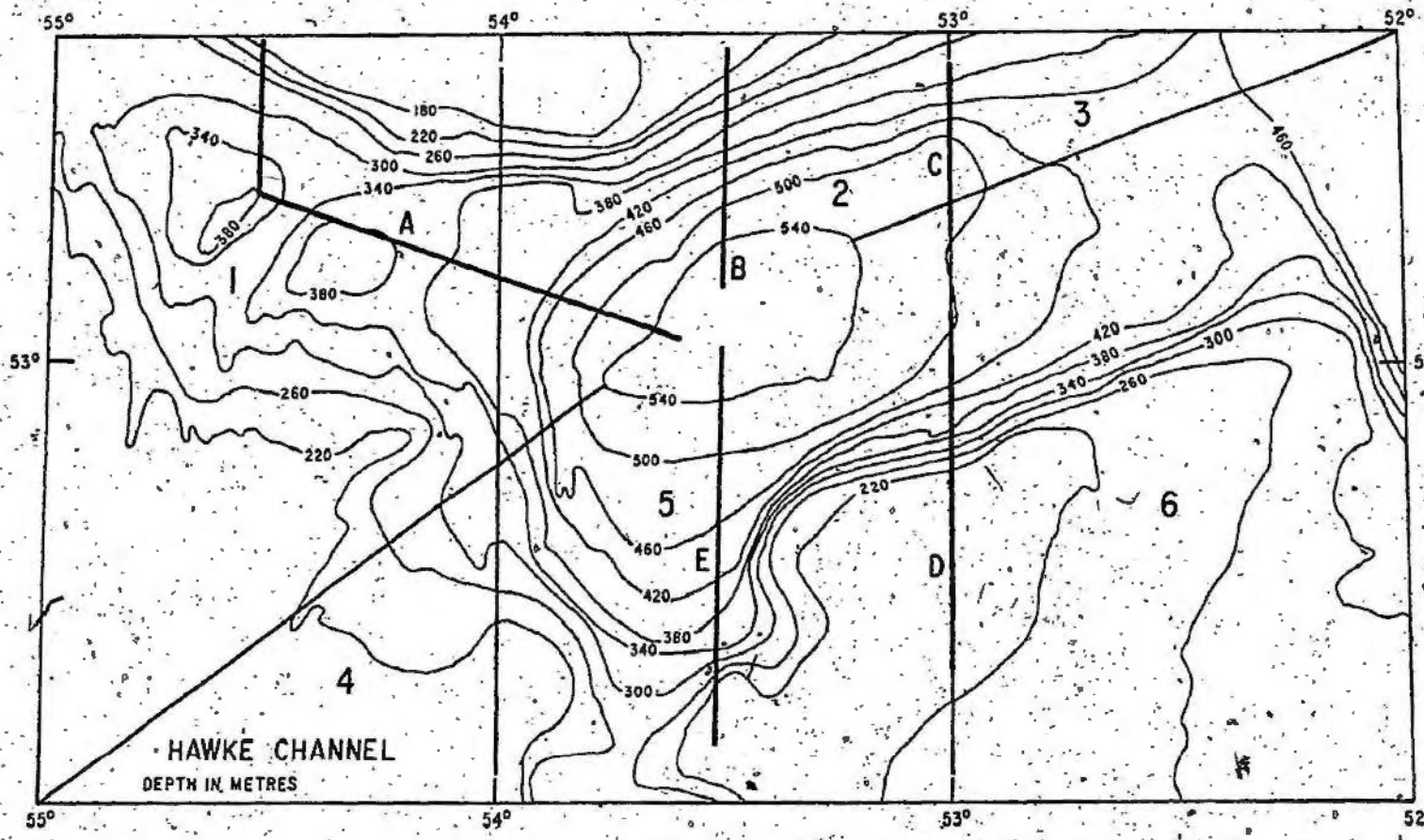


Fig.2 c) Bathymetry and survey lines (A-E) in the Hawke Channel.

part of the orbit of the eye and the posterior middorsal margin of the carapace (Butler 1980). Measurements were made using Fowler dial calipers to the nearest 0.5 mm in routine random sampling but to 0.1 mm in cases where more precision was required.

Random samples from each fishing set, usually consisting of 200 animals or more, were collected for studies on distribution and abundance. Length frequencies from all surveys (1979-81) were combined over 100 m depth intervals and numbers were expressed as a percentage.

In 1980 and 1981 fishing sets were made in the same general area to monitor patterns of diel variability in catch rates. Fishing was continued until there was approximately one set for every hourly interval in the 24-hour cycle. This sampling occurred on July 27, 28, and 29 in 1980 and July 25 and 26 in 1981. The area fished in both years was the northern Hopedale Channel in approximately 550 m of water in 1980 and 350 m in 1981. Set and catch details and shrimp length frequencies were obtained from each fishing set.

Sex and Maturity

Two random samples of shrimp were examined for sex and maturity. These were taken in 560 m of water in the Cartwright Channel (380 specimens), and in 409 m in the Hopedale Channel (n = 350) on July 14 and 18, 1980, respectively. Carapace length was recorded to the nearest 0.1 mm and subsequently combined to 0.5 mm. Observations on sex and maturity were recorded. Maturity was determined in a general sense, referring to stages in the ontogeny of a protandric hermaphrodite rather than the more classical interpretation involving condition of the gonads. Females were categorized as first year

spawners or multiple spawners (spawning in more than one year) based on the prominence of sternal spines (McCrary 1971). Animals were assigned to one of four groups: males (including immature males), transitionals, first-year spawning females, and multiple spawners. Sex was determined by Rasmussen's (1953) method of examination of the first pleopod, recently described by Butler (1980).

Length frequencies from all three channels were obtained during a research cruise of the A.T. CAMERON in September 1978. This vessel used a Yankee 36 shrimp trawl (Appendix II) lined in the last 3 m of codend with 13 mm mesh; otherwise, mesh size was 38 mm throughout. The headline of the trawl was 18.3 m and the footrope, 24.4 m. The estimated horizontal opening of the trawl was 10.7 m (Carrothers and Foulkes 1972). Towing characteristics were essentially the same as for the Sputnik 1600 trawl (vide pg. 9). Animals were separated into ovigerous (egg-bearing) and non-ovigerous groups. All length frequencies were adjusted to total catch weight and expressed in terms of number caught per standard 30 minute tow. Total animals measured were 6,435, 7,313, and 2,055 for Hopedale, Cartwright, and Hawke Channels, respectively. Ogives of percent male and percent non-ovigerous versus carapace length were fitted by eye.

Weight-Length Relationships

Random samples of shrimp from the three Labrador Channels were collected during a cruise of the M.V. ZAGREB from July 6 to August 4, 1979. Each sample was preserved in 10% formalin (1 part 40% formaldehyde, 9 parts sea water) and returned to the laboratory for detailed examination. Shrimp from each channel (n = 309, 249, and 239 from

Hopedale, Cartwright, and Hawke, respectively) were measured for carapace length (to the nearest 0.1 mm) and for total weight (to the nearest 0.01 g). Samples were obtained at a time when females were not ovigerous.

Weight-length relationships of the form $w = al^b$ were derived, where w is the weight of the animal in grams, l is the length in mm and a and b are constants. Least squares linear regression of log (base 10) weight on log length provided the estimates for a and b. The log-log equation takes the form: $\log w = \log a + b (\log l)$

Statistical methods of linear regression and analysis of covariance were performed on transformed data according to standard methods described by Snedecor and Cochrane (1967) and Zar (1974). Relationships for fresh and preserved shrimp from the Gulf of St. Lawrence ($n = 315$) were also compared.

Fecundity

Ovigerous female shrimp were collected in the three Labrador Channels from 1974 to 1979[3]. Hopedale Channel was sampled in August and November 1977 and September, 1978; Cartwright in September, 1978 and November 1979; and Hawke in August and November-December, 1974, September, 1975 and August, 1977.

Individual specimens were placed in bottles containing 10% formalin and returned to the laboratory for counting the eggs. Animals were selected from a variety of lengths to represent as many female size groups as possible. It was assumed that within any length group the selection (in terms of fecundity) was random. Carapace lengths of the shrimp were measured to the nearest 0.5 mm.

[3]The material collected prior to 1978 was made available to the author through the courtesy of Research and Resource Services, Fisheries and Oceans, St. John's, Newfoundland.

All eggs, including those assumed to be non-viable (see parasite section), were carefully removed from the abdominal appendages (pleopods), spread in a Petrie dish, and then dried overnight in a Thelco Precision oven at 60°C. After drying, the eggs were separated and counted.

Equations for the relationship between numbers of eggs and carapace length for each sample were determined by linear regression utilizing log-log (base 10) transformation. Samples were compared by analysis of covariance. Homogeneity of variance was determined by F test and Bartlett's test (described in Snedecor and Cochrane 1967).

Accuracy of the counts was determined by recounting the eggs from five animals. The differences from the initial counts were small and varied from -1.53% to +0.88%. The difference for the total number of eggs counted and recounted was -0.15%.

Food and Feeding

A total of 3,808 shrimp was examined for stomach contents. These were collected during cruises of various research and commercial vessels in the Hawke and Hopedale Channels between November 12, 1973 and September 29, 1978[4]. Thirteen samples comprised the total: November 1973, December 1974, July and September (2) 1975, August 1976 and August 1977 in Hawke Channel; and August 1977, November 1977, August 1978 (2) and September 1978 (2) in Hopedale Channel. Depth of water ranged from 179 to 439 m.

Random samples were selected from the total catch in each case. Research samples differed from commercial in that a small-meshed

[4]Samples prior to 1978 were made available to the author through Research and Resource Services, Fisheries and Oceans, St. John's, Newfoundland.

liner was used in the former to prevent the escape of small animals. Selectivity was more pronounced in the commercial samples. All shrimp were preserved in 10% formalin and returned to the laboratory for detailed observation. Stomachs were dissected out and placed in tap water in a Petrie dish and contents were removed. These were examined under a Wild dissecting microscope at various magnifications. Degree of fullness was estimated as full, some and empty and contents were identified in eight general groups according to the method of Squires (pers. comm.). These groups were: detritus, phytobenthos, sand (or mud), Crustacea, Polychaeta, Foraminifera, unspecified digested material and other. Food items from each stomach were recorded as primary, secondary, or tertiary in importance based on the relative amounts present.

In addition, observations were made on carapace length, sex, and maturity. Set detail information included date, position, time, and depth.

Parasites of Shrimp Eggs

A sample of 48 female shrimp was taken from the Cartwright Channel in November, 1979 to determine fecundity (see fecundity section). Eggs were preserved in the manner described previously and returned to the laboratory for detailed examination. All shrimp were measured to the nearest 0.1 mm and eggs were counted. Those considered 'non-viable' because of their swollen, opaque appearance were separated from the 'viable' eggs in the clutch and enumerated. At least ten (or the total sample if $n \leq 10$) non-viable eggs from each clutch were examined using a Zeiss compound microscope.

These eggs were smeared under a coverglass and carefully scanned for the presence or absence of parasites.

Photomicrographs of preserved unstained and stained material were taken at various magnifications. The stain used was Giemsa colophonium (Bray and Garnham 1962).

Muscle Necrosis

A sample of nine shrimp was taken from various locations off the Labrador coast in July, 1980. Eight of these were taken in the Cartwright Channel and one in the Hopedale Channel. The shrimp were sampled because of their 'cooked' appearance (during cooking the shrimp muscle becomes opaque).

All tissues for microscopy were fixed in Bouin's fluid. The cephalothorax was removed from each animal and placed in the fixative in an appropriately labelled vial. The shell was removed from the abdomen and placed in a separate vial. The abdomen was then cut into six sections, numbered from the anterior end and each was placed in a vial. On return to the laboratory the tissues were dehydrated and embedded in paraffin, and transverse sections (7 μm thick), prepared from the posterior abdominal muscle following conventional histological procedures, were stained with hematoxylin and eosin (Pearse 1968) as well as Giemsa colophonium (Bray and Garnham 1962). Smears were also made of abdominal muscle before dehydration and stained with Giemsa. Photomicrographs were taken at various magnifications using a Zeiss photomicroscope. As a control, normal shrimp muscle tissue also was examined.

Tissues also were processed by conventional electron microscope methods and examined with a Zeiss electron microscope. (Details are given in Appendix IV.)

RESULTS

Distribution

A. Horizontal Distribution

Catches per standard fishing tow for each channel for 1979-81 combined and for each year are shown in Figures 3, 4, and 5. Where positions were approximately the same, the level given respresents a mean for all catch data combined.

The Hopedale Channel is a large area extending approximately 160 km in a northwest-southeast direction (Fig. 2a). For survey purposes the area was divided into three zones. The northern zone is a relatively narrow trough of deep water with steep sides. The seaward side is suitable for fishing while the slopes from the deepest areas on the western side are very irregular and not fishable using otter trawls. Catch rate data showed that shrimp were most abundant in this northern part of the channel with best catches occurring at depths around 300 m and greater (Fig. 3a, Table 1). Abundance of shrimp was also high in the deepest strata (> 500 m). Catches occasionally exceeded 1000 kg/30 minute tow. Abundance on the western slope was not estimated because of untrawlable bottom. Bottom temperatures in the area of high abundance generally ranged between 2.6 and 3.6°C.

The central zone is characterized by more regular topographic conditions. The shallower, eastward part of the area is actually the 'saddle' which extends over the Labrador Shelf. Bottom suitable

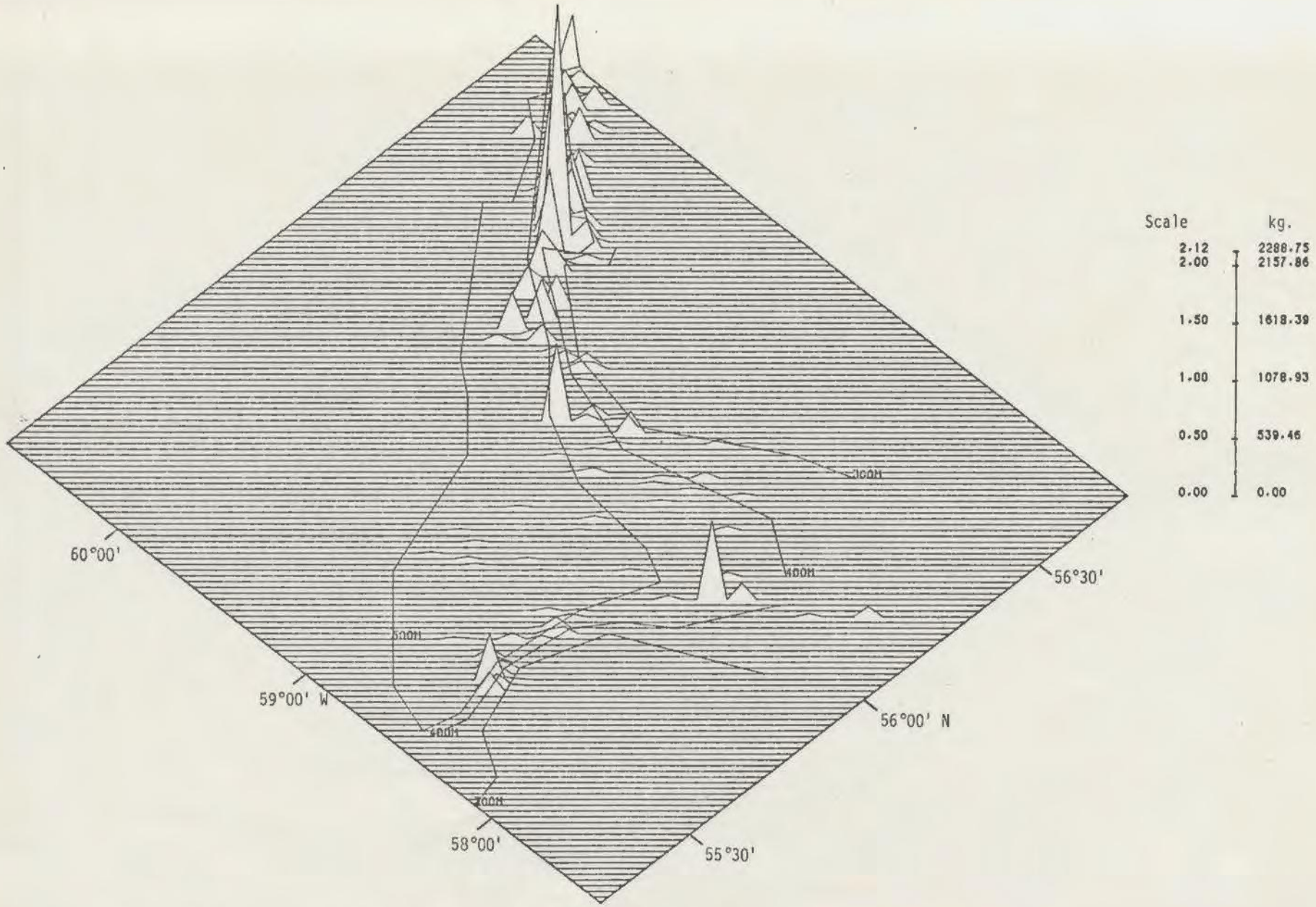


Fig.3a) Shrimp catches per 30 minute tow - Hopedale Channel, 1979 - 1981 (July).

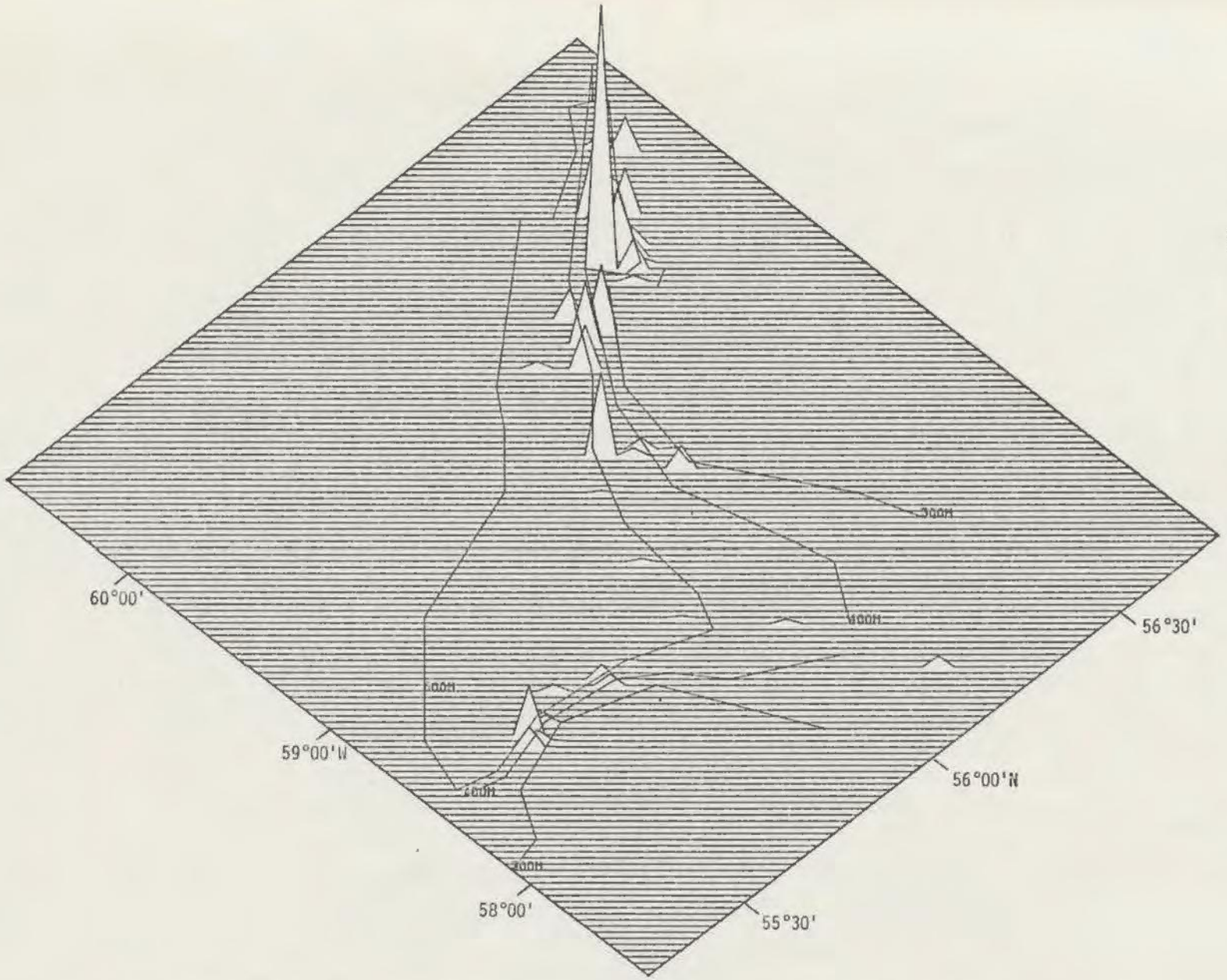


Fig.3 b) Shrimp catches per 30 minute tow - Hopedale Channel, 1979 (July 9-17).

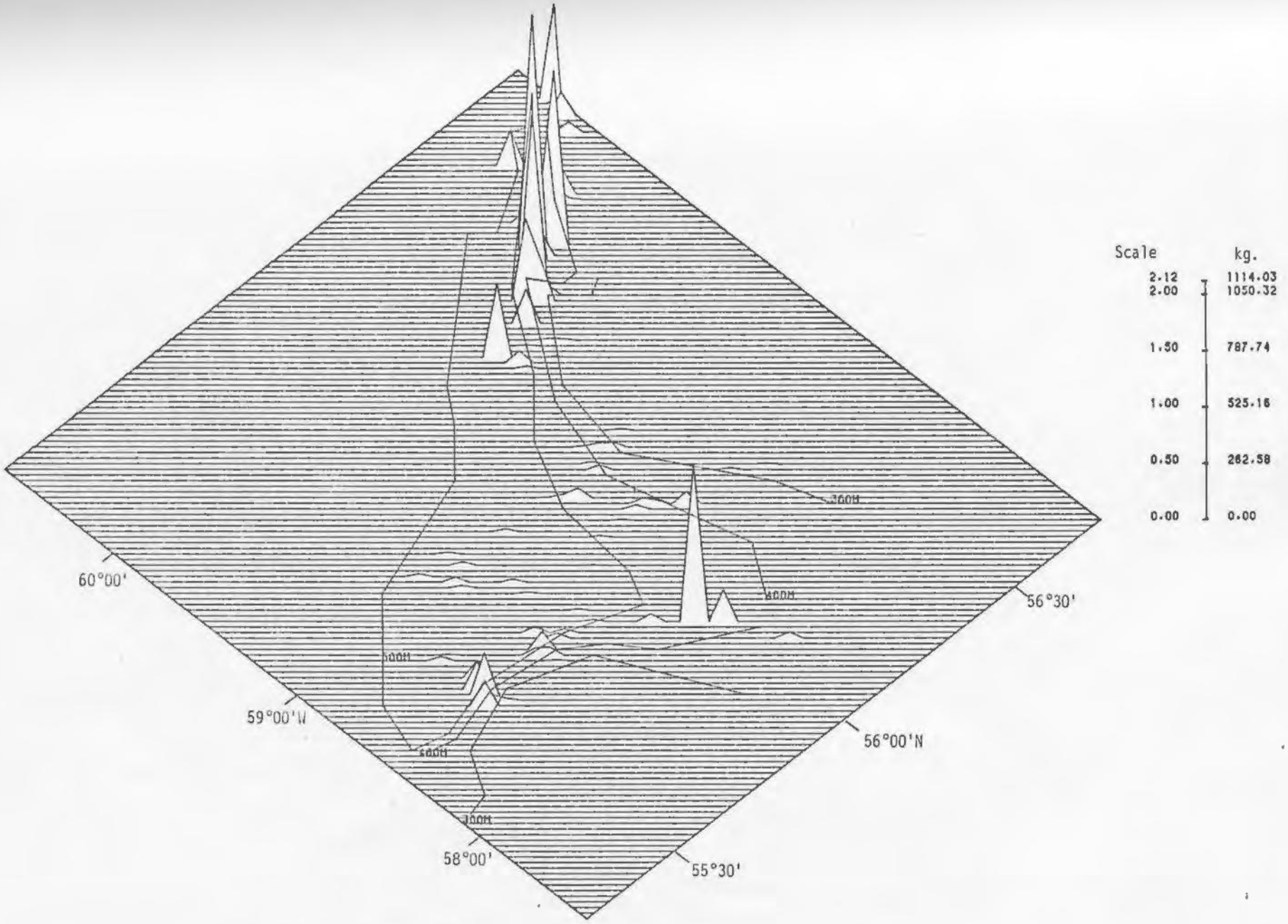


Fig.3 c) Shrimp catches per 30 minute tow - Hopedale Channel, 1980 (July 16-26).

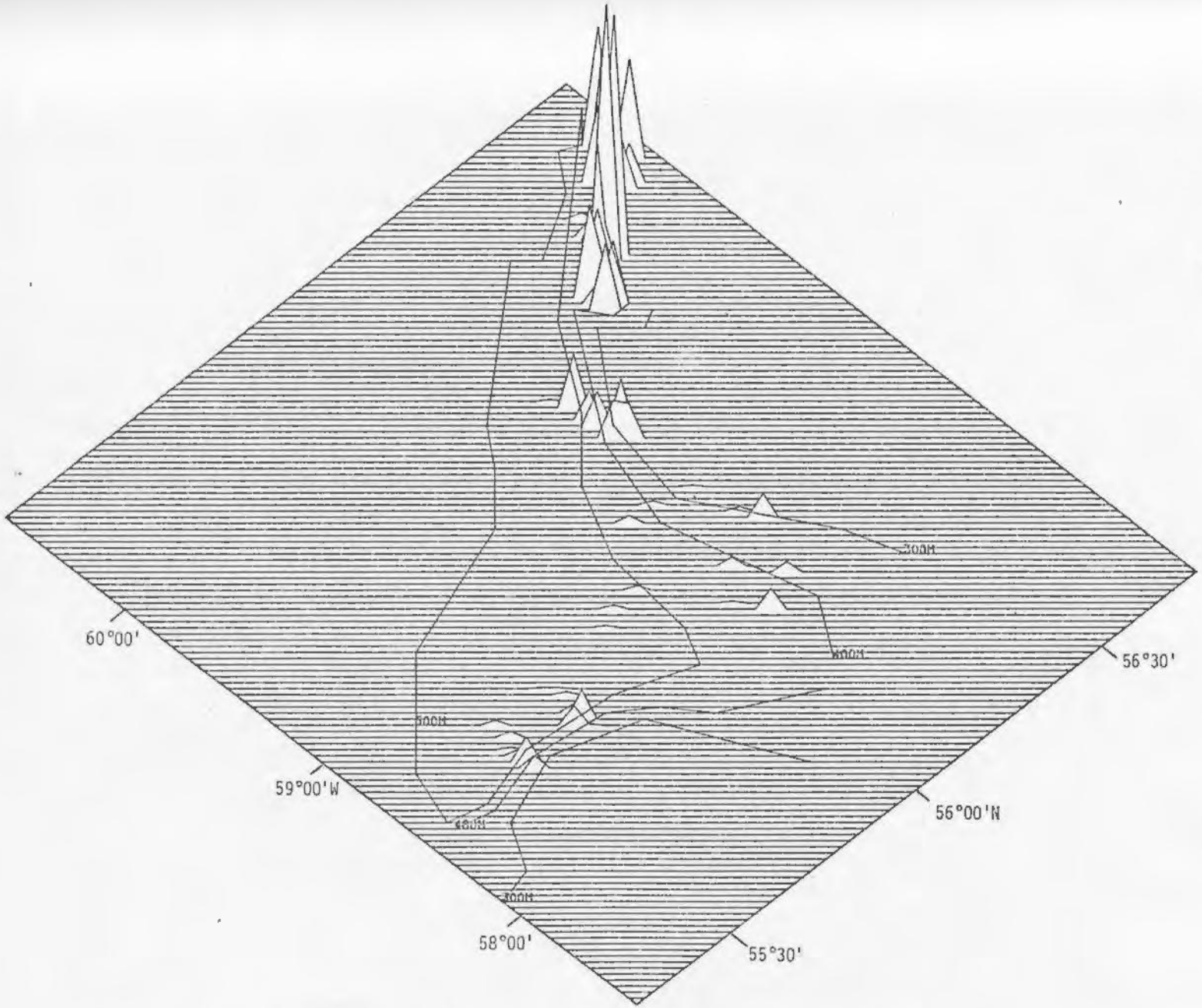


Fig. 3d. Shrimp catches per 30 minute tow - Hopedale Channel, 1981 (July 18-27).

Table 1. Av. catch (kg) per standard 30 minute tow and bottom temperature (°C) per depth stratum, July 1979-81.

Hopedale Channel

Zone[1]	Depth range (m)	1979[2] No. sets	1979[2] Av. catch	1979[2] Av. temp.	1980[3] No. sets	1980[3] Av. catch	1980[3] Av. temp.	1981[4] No. sets	1981[4] Av. catch	1981[4] Av. temp.	1979-81 No. sets	1979-81 Av. catch	1979-81 Av. temp.
1	202-238	2	24.5	-	-	-	-	1	62.6	0.5	3	37.2	0.5
	239-274	2	136.4	2.5	2	5.7	1.7	2	55.1	0.7	6	65.7	1.6
	275-311	2	24.3	2.6	3	11.0	2.2	3	99.9	1.6	8	47.7	2.1
	312-348	2	54.3	2.9	4	67.3	2.7	4	289.0	2.6	10	153.4	2.7
	349-384	2	148.7	2.9	4	38.1	2.9	3	272.4	3.3	9	140.8	3.0
	385-421	2	340.4	3.1	4	67.0	3.0	3	95.0	3.1	9	137.1	3.1
	422-457	2	265.4	3.5	4	206.9	3.2	3	137.3	3.1	9	196.7	3.2
	458-494	2	803.8	3.3	4	354.5	3.0	3	78.0	3.2	9	362.2	3.1
	495-530	2	323.1	3.2	3	613.3	3.3	3	56.3	3.6	8	331.8	3.4
	531-567	2	1269.6	3.1	2	888.6	3.2	1	9.5	3.2	5	865.2	3.2
	568-603	1	68.0	3.2	1	305.3	-	1	24.5	3.2	3	132.6	3.2
	>603	1	37.2	3.2	1	395.1	3.2	-	-	-	2	216.2	3.2
2	275-311	-	-	-	3	9.2	2.6	2	22.5	2.9	5	14.5	2.7
	312-348	2	6.4	3.5	2	14.5	3.0	1	8.2	3.7	5	10.0	3.3
	349-384	2	96.6	3.3	3	30.2	3.1	2	12.9	3.4	7	44.2	3.2
	385-421	2	3.2	3.4	4	50.4	3.2	2	14.5	3.7	8	29.6	3.4
	422-457	3	256.6	3.3	3	259.2	3.2	1	35.8	3.7	7	226.2	3.3
	458-494	2	5.0	3.4	3	28.4	3.4	1	3.3	-	6	16.4	3.4
	495-530	3	2.5	3.4	3	11.0	3.6	1	8.4	3.8	7	7.0	3.5
	531-567	3	13.7	3.2	3	4.1	3.4	1	7.2	3.3	7	8.7	3.3
	568-603	2	1.7	3.2	2	13.9	3.5	1	3.4	3.3	5	6.9	3.4
	>603	-	-	-	3	10.7	3.4	-	-	-	3	10.7	3.4
3	275-311	-	-	-	2	6.9	2.2	-	-	-	2	6.9	2.2
	312-348	2	6.9	1.2	2	28.3	1.6	2	7.9	2.5	6	14.4	1.8
	349-384	2	60.3	2.1	2	74.5	2.7	2	16.4	2.4	6	50.4	2.4
	385-421	2	134.8	1.9	2	119.4	3.1	1	60.8	2.8	5	113.8	2.6
	422-457	2	96.6	2.5	2	128.4	3.0	2	32.0	2.9	6	85.7	2.8
	458-494	1	0.9	3.3	2	76.7	3.0	2	31.1	3.1	5	43.3	3.1
	495-530	2	1.8	3.0	2	52.8	2.9	2	16.9	3.3	6	23.8	3.1
	531-567	-	-	-	2	69.0	3.3	2	4.9	3.5	4	37.0	3.4
	568-603	2	0.9	3.1	2	31.1	3.2	2	6.4	3.4	6	12.8	3.2
	>603	-	-	-	2	15.3	3.6	2	5.7	3.3	4	12.1	3.5

[1]See Fig. 2a.
[2]July 9-17
[3]July 16-26
[4]July 18-27

for trawling was readily found but shrimp concentrations were lower than in the northern zone. Best catches occurred in depths between 350-450 m but were generally less than 100 kg per tow. The saddle generally yielded low catches of shrimp as did the deepest part of the central Hopedale Channel at depths greater than 530 m. Temperature between 350 and 450 m averaged 3.3°C during 1979-81.

The southern zone of the Hopedale Channel is also irregular in topography, with a steep fishable area on the seaward side of the channel. Catches, in comparison to the northern zone, were also low in this area (< 100 kg/standard tow) with highest concentrations occurring at depths between 350 and 550 m at temperatures around 2.0 to 3.5°C.

Figures 3b, c, and d and Table 1 show the distribution between years in the Hopedale Channel. Highest catch rates occurred in the northern area in all three years with consistently lower catches in southern areas. Catches obtained in each year indicate a marked change in distribution between 1979/80 and 1981. There also appears to be a considerable decrease in abundance between 1980 and 1981. Although temperatures remained relatively constant between years (generally 2.6 to 3.6°C) in areas of greatest abundance, research catch data showed areas of highest concentration at depths greater than 400 m in 1979 and 1980 but between 300 and 450 m in 1981.

The Cartwright Channel is an area much smaller than the Hopedale Channel, with shrimp distribution occurring over a distance of approximately 40 km in a general north-south direction (Fig. 2b).

The Cartwright 'saddle' is farther north, and did not contain large concentrations of shrimp. As in the Hopedale Channel, trawlable bottom was only found on the seaward (eastern) side of the depression. Concentrations of shrimp were found at depths greater than 350 m (Fig. 4a, Table 2) where bottom temperatures ranged from approximately 2 to 3°C.

Differences in distribution and abundance between years are shown in Table 2 and Figures 4b, c, and d. Areas of highest density were found in the deepest strata (> 400 m) in both 1979 and 1980. In 1981, highest densities occurred at shallower depths generally between 350 and 500 m. Large catches were obtained throughout the channel in both 1979 and 1980 but, in 1981, best catches occurred in the more northern areas. Additional sets over the saddle in 1981 indicated areas of substantial concentration did not extend far beyond the boundaries given in the figures.

The data also suggested that shrimp were concentrated in a smaller area in 1981 than in the previous two years. This was evident from the distribution and relative height of the peaks in Fig. 4b, c, and d. Temperatures (approximately 2.5 to 3°C) were consistent between years where shrimp were most abundant.

The Hawke Channel (Fig. 2c) has been defined in more detail, topographically, than either of the other two areas (Warren 1976). This channel is unlike the others as trawlable bottom can be found on all sides. However, there is a saddle which extends over the Labrador Shelf as in the other two previously mentioned areas. The survey area of the Hawke Channel was comparable to the Hopedale Channel. Catch rates were highest in northern parts of the Channel

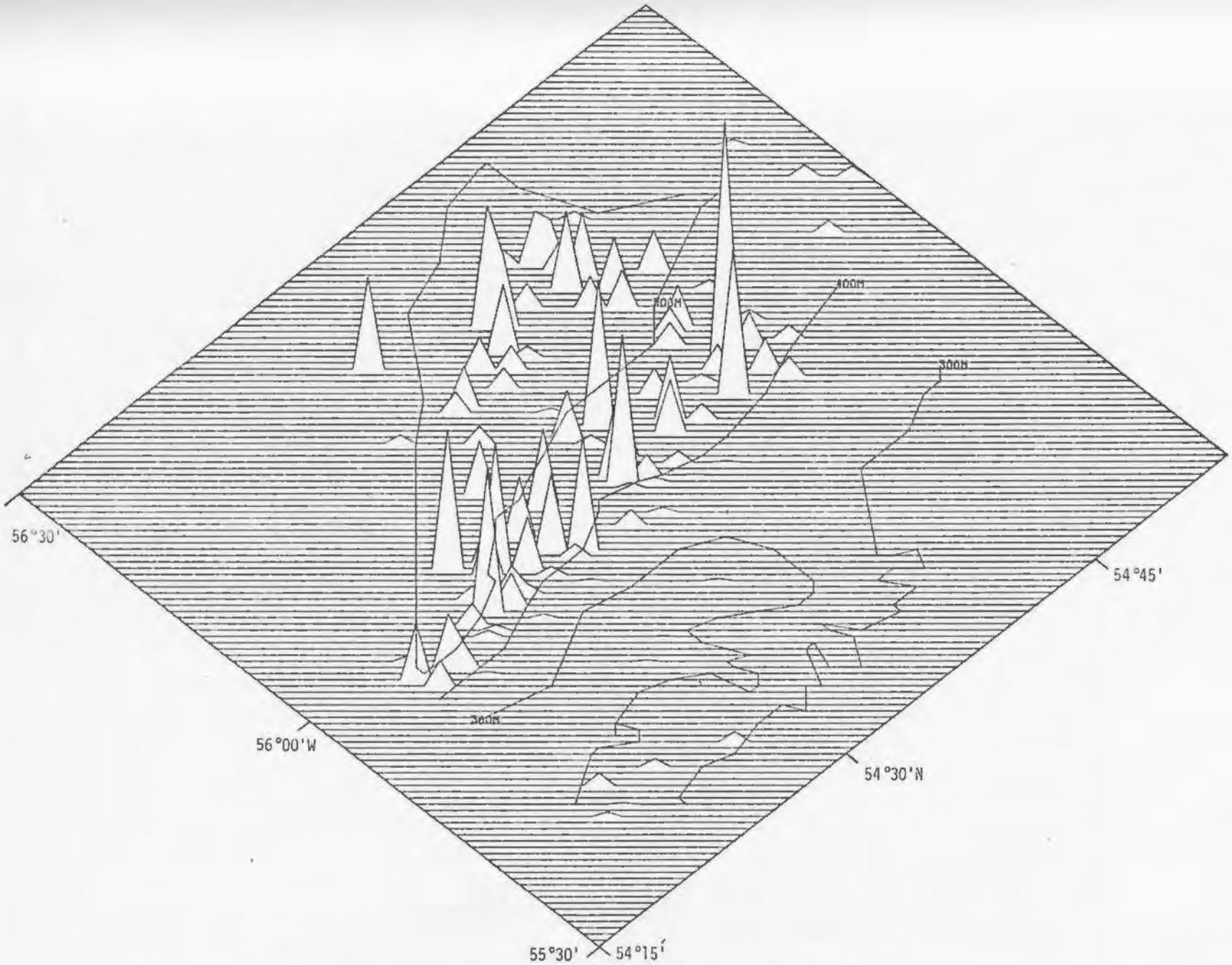


Fig.4 a) Shrimp catches per 30 minute tow - Cartwright Channel, 1979 - 1981 (July).

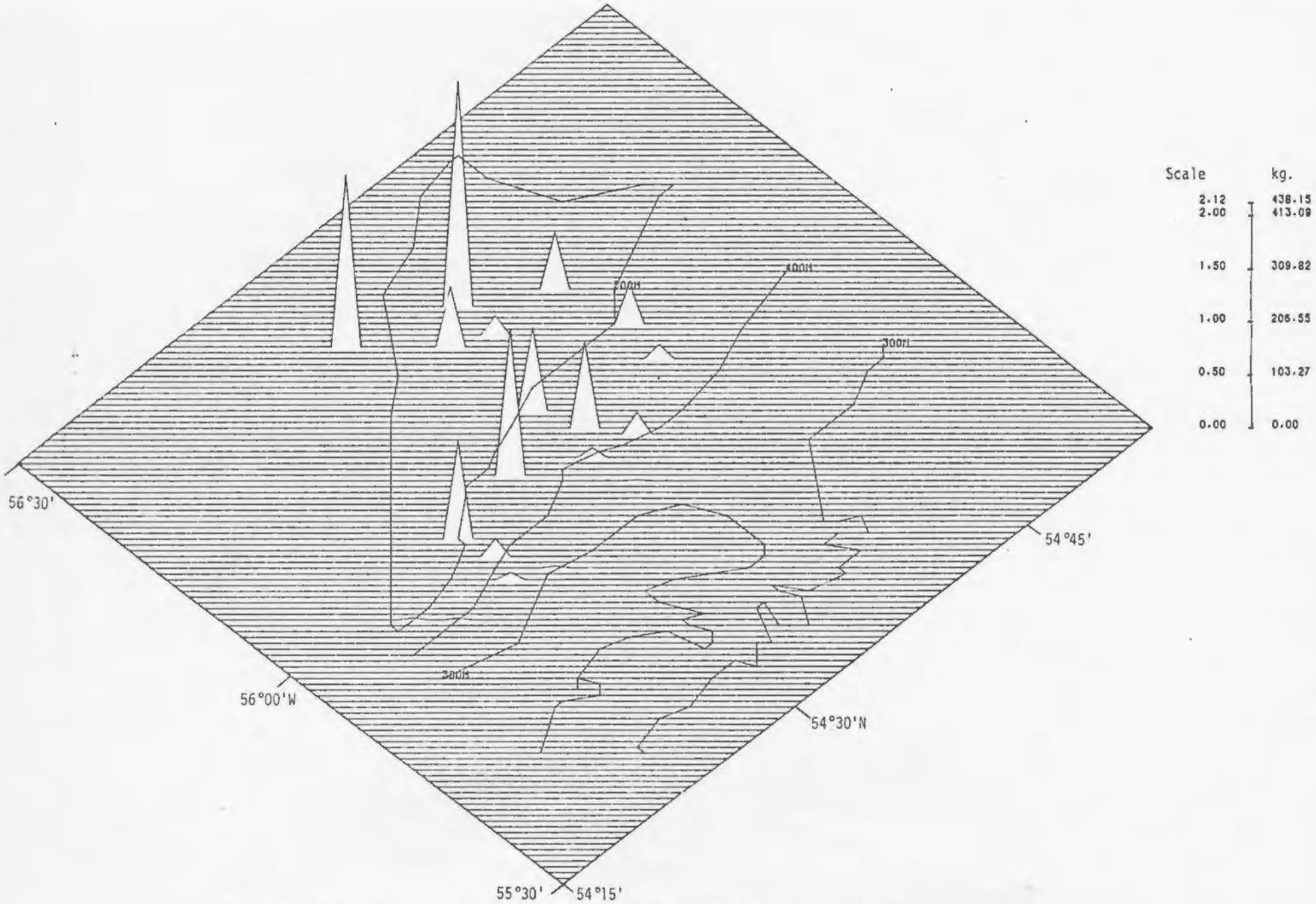


Fig.4b) Shrimp catches per 30 minute tow - Cartwright Channel, 1979 (July 22-24).

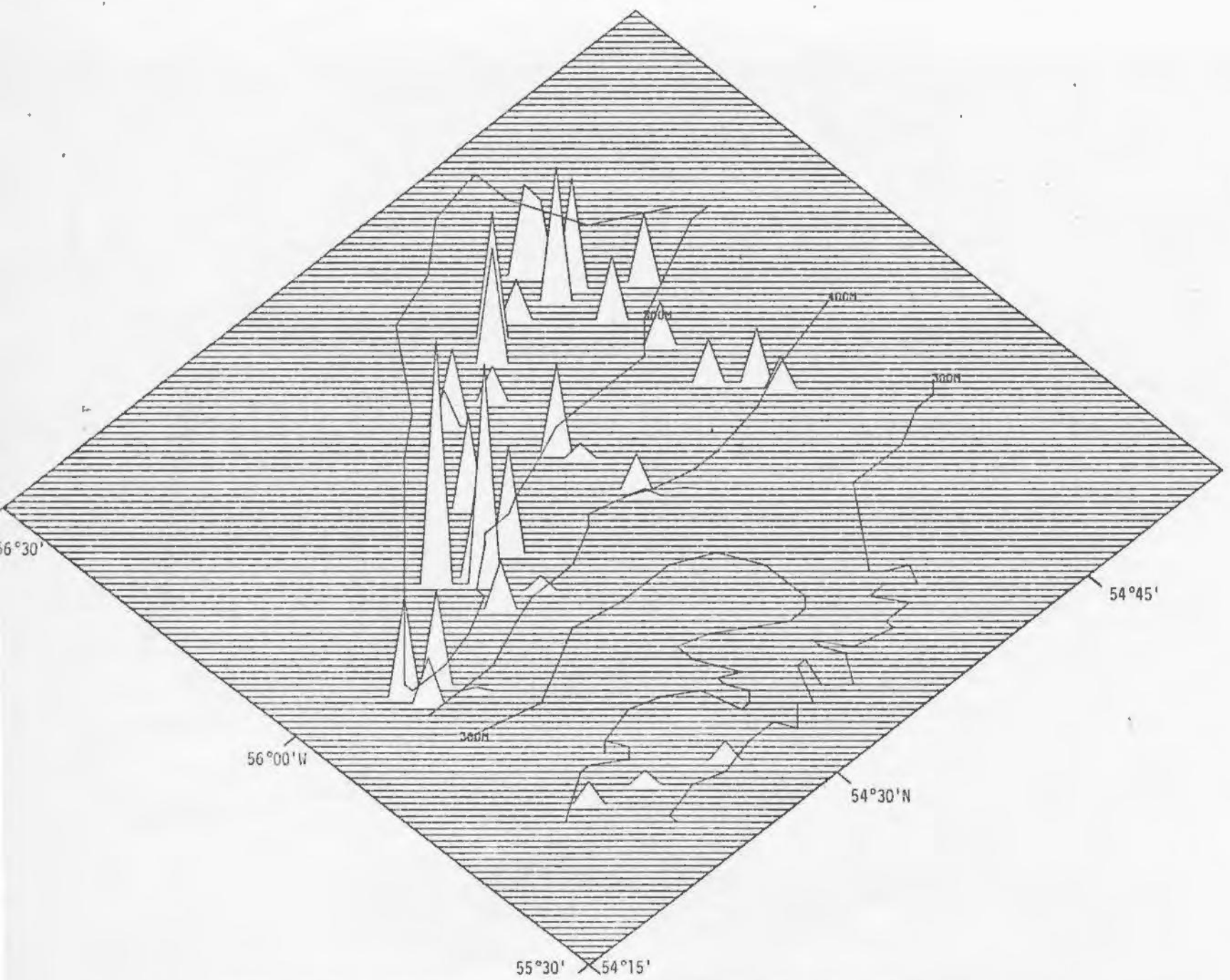


Fig.4 c) Shrimp catches per 30 minute tow - Cartwright Channel, 1980 (July 11-15).

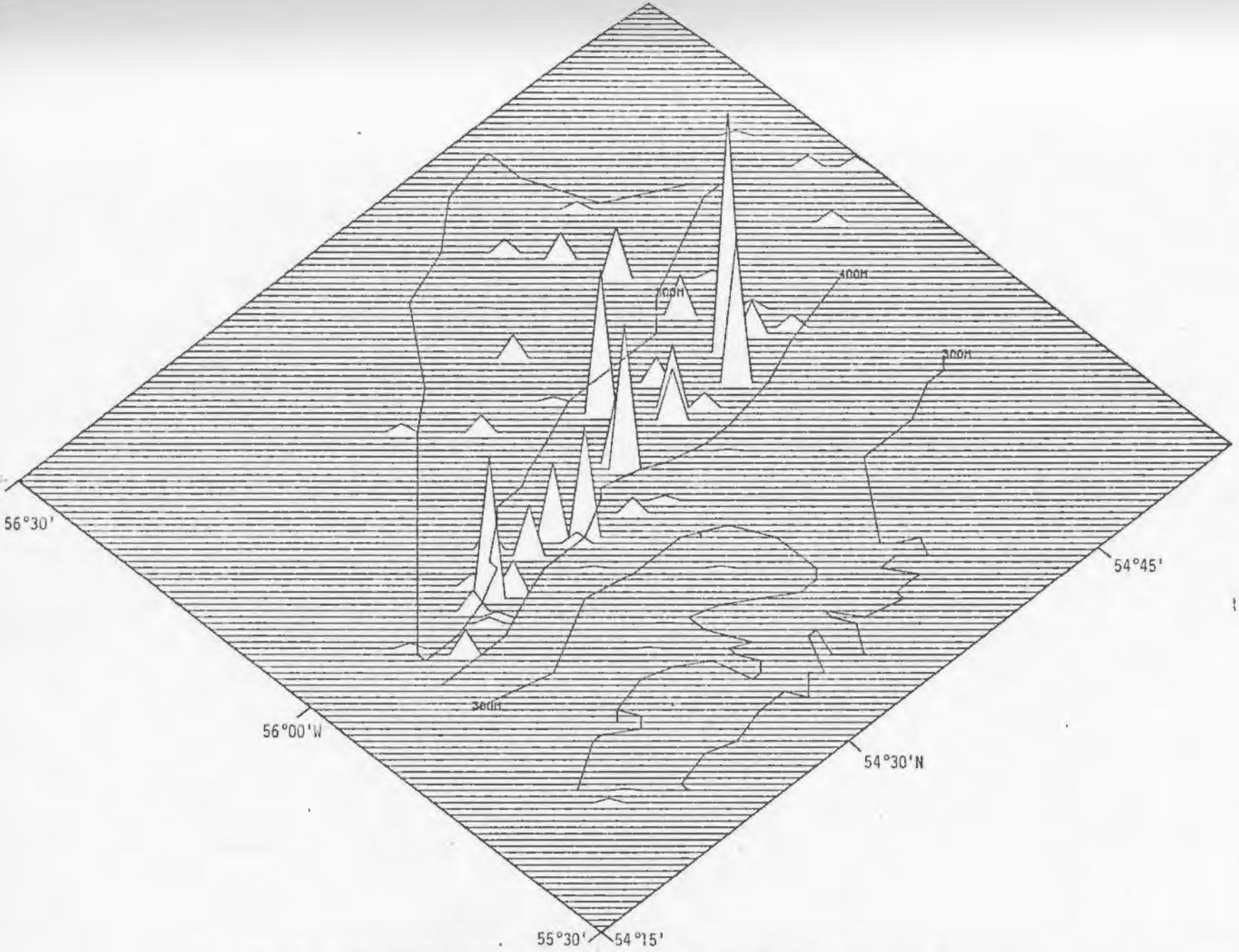


Fig. 4d. Shrimp catches per 30 minute tow - Cartwright Channel, 1981 (July 3-7).

Table 2. Av. catch (kg) per standard 30 minute tow and bottom temperature (°C) per depth stratum, July 1979-81.

Cartwright Channel

Depth range (m)	1979[1] No. sets	1979[1] Av. catch	1979[1] Av. temp.	1980[2] No. sets	1980[2] Av. catch	1980[2] Av. temp.	1981[3] No. sets	1981[3] Av. catch	1981[3] Av. temp.	1979-81 No. sets	1979-81 Av. catch	1979-81 Av. temp.
<300							8	1.8	1.5	8	1.8	1.5
300-350	3	2.9	1.5	5	23.0	1.1	5	10.2	2.2	13	13.4	1.6
350-400	4	8.4	2.3	6	48.9	1.8	9	118.3	2.4	19	73.3	2.2
400-450	6	45.8	2.5	6	159.9	2.2	10	350.3	2.8	22	215.3	2.6
450-500	4	214.3	2.9	6	136.1	2.7	11	178.2	2.7	21	173.1	2.7
500-550	5	178.7	3.1	8	195.8	2.9	3	67.4	3.0	16	166.4	3.0
550-600				6	226.8	3.0	3	56.8	2.8	9	170.1	2.9

[1]July 22-24
[2]July 11-15
[3]July 3-7

between 350 and 500 m at temperatures near 3.0°C (Fig. 5a and Table 3). Examination of distribution of catch rates between years (Fig. 5b, c, and d) showed consistency in areas of abundance between 1979 and 1980 but an overall scarcity of shrimp in the same areas in 1981. It was apparent that abundance as well as density decreased from 1979 to 1981. Temperatures were relatively constant between years but records showed slightly warmer water in the deeper areas (approximately 3.5°C) in 1980. In 1979 and 1981, bottom temperatures were closer to 3°C (Table 3).

B. Size Distribution

Size distributions by depth for each channel for the period 1979-81 are given in Fig. 6. Six 100 m depth strata were sampled in the Hopedale Channel (Fig. 6a). Abundance of relatively small animals (< 20 mm carapace length) decreased with depth. In the shallowest depth interval, only one modal size group was evident (around 17 mm) while in deeper strata other modes were observed (particularly at 24 mm). In the deepest zone only one size group, which consisted totally of females was evident between 24 and 26 mm. The precision of measurement to 0.5 mm carapace length generates some noise in the length frequencies. Interpretation is made from general observations only, and such anomalies are not considered.

The trend so well-defined in the Hopedale Channel was not so apparent in the Cartwright Channel (Fig. 6b). Animals over the complete size range were evident in the shallowest depth zone (201-300 m). The three remaining zones reflected the trend of

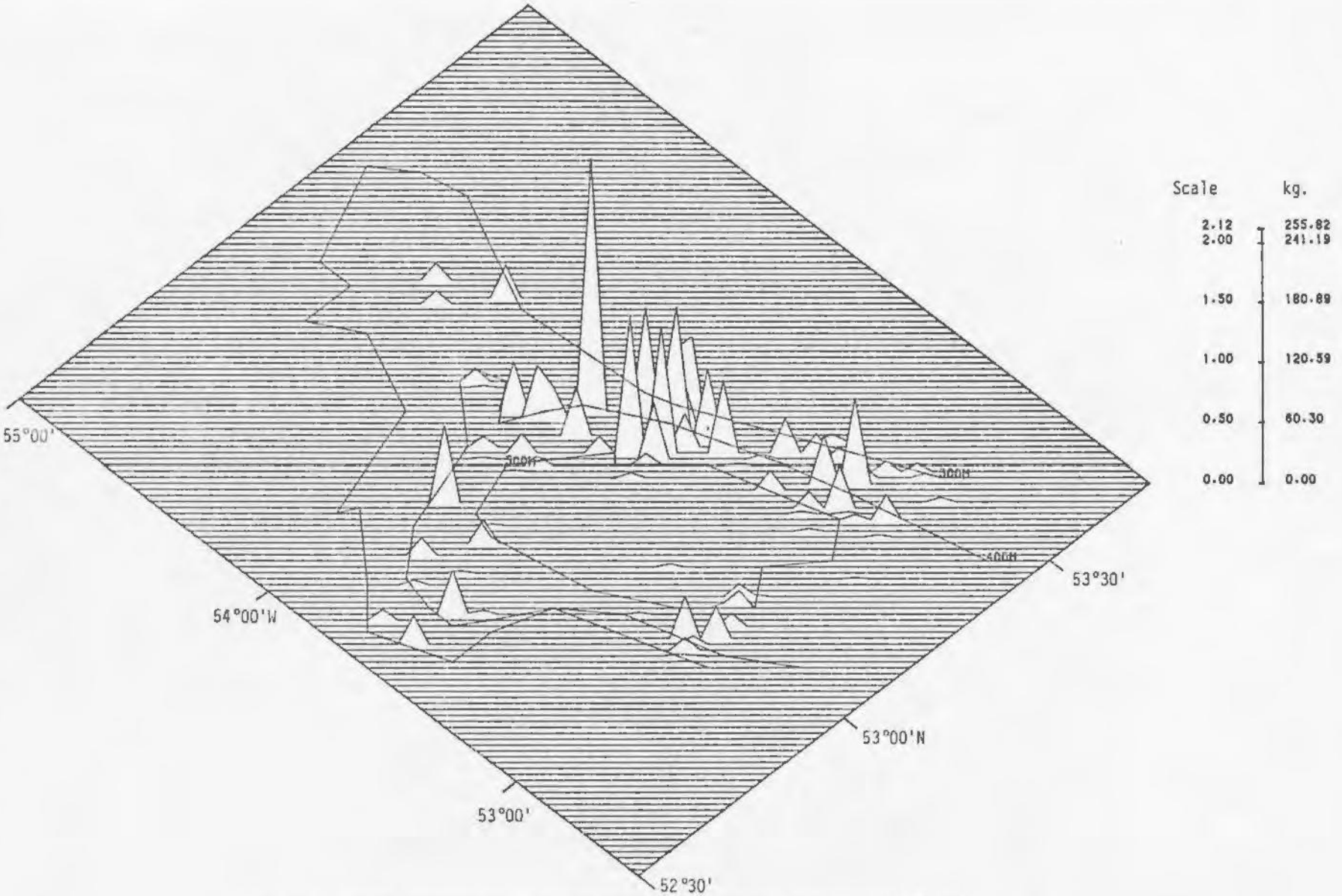


Fig.5 a) Shrimp catches per 30 minute tow - Hawke Channel, 1979 - 1981 (July).

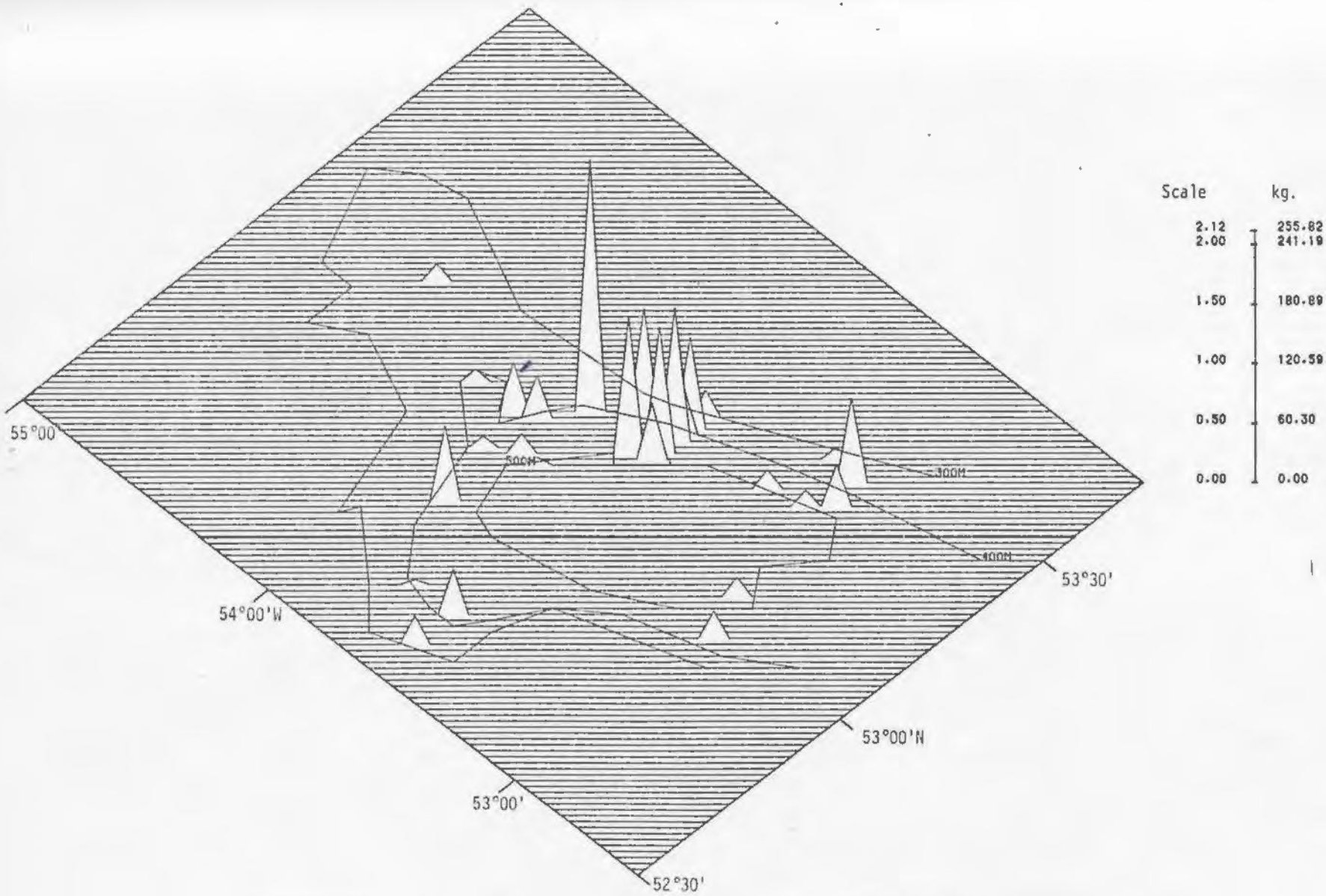


Fig.5 b) Shrimp catches per 30 minute tow - Hawke Channel, 1979 (July 17-22).

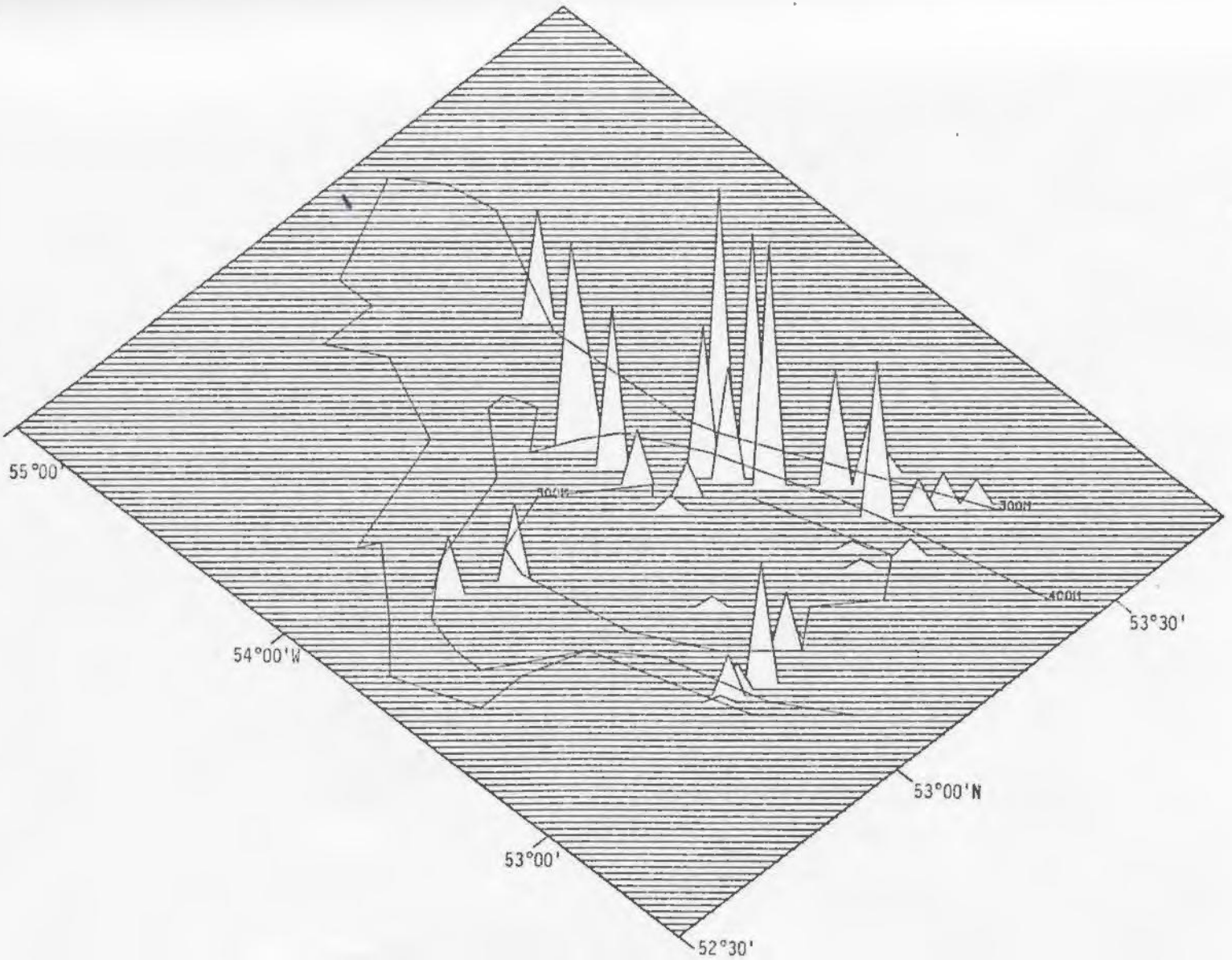
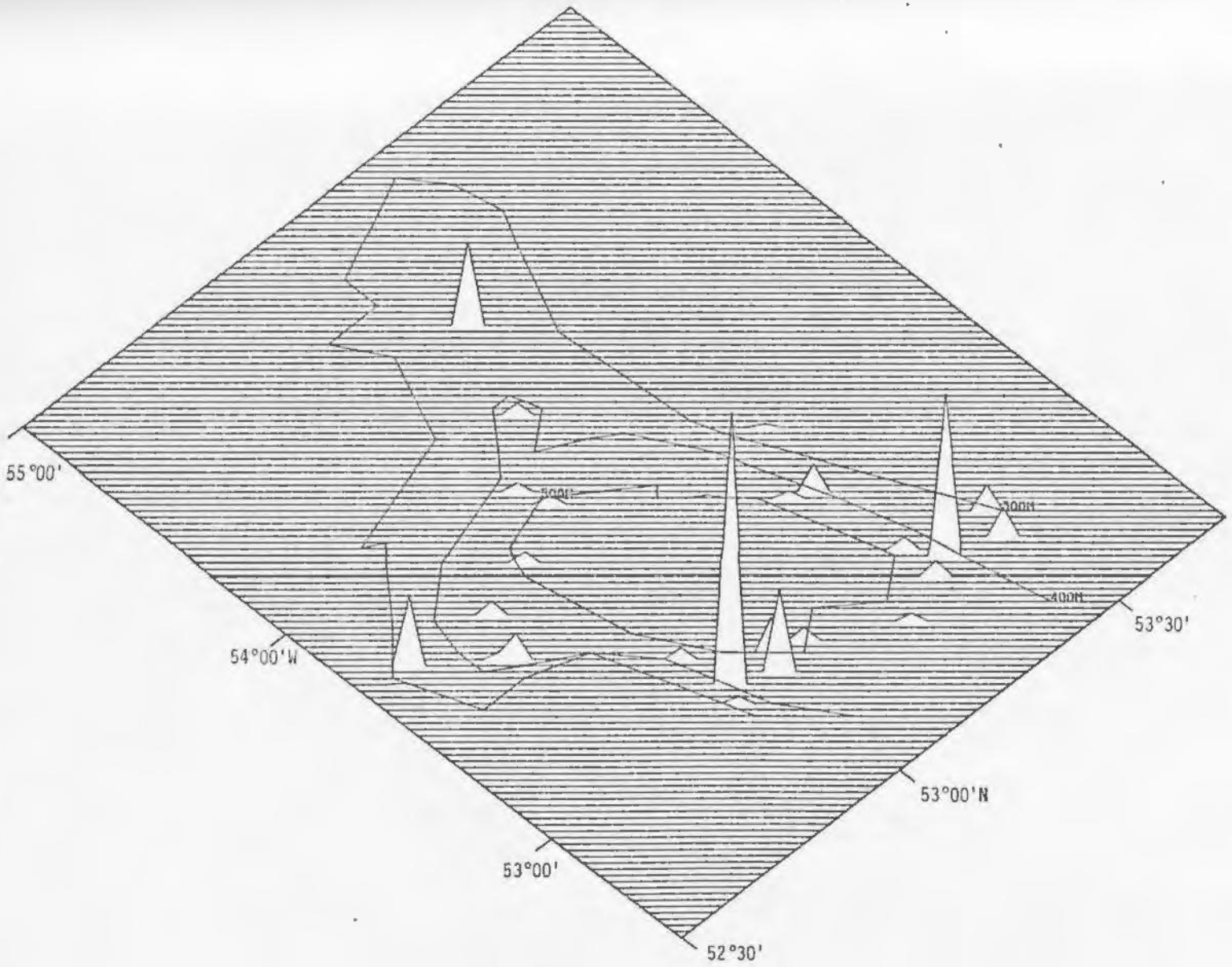


Fig.5 c) Shrimp catches per 30 minute tow - Hawke Channel, 1980 (July 30-Aug.2).



Scale	kg.
2.12	42.60
2.00	40.16
1.50	30.12
1.00	20.08
0.50	10.04
0.00	0.00

Fig. 5d. Shrimp catches per 30 minute tow - Hawke Channel, 1981 (July 8-11).

Table 3. Average catch (kg) per standard 30 minute tow and bottom temperature (°C) per depth stratum, July 1979-81.

Hawke Channel

Zone[1]	Depth range (m)	1979[2] No. sets	1979[2] Av. catch	1979[2] Av. temp.	1980[2] No. sets	1980[2] Av. catch	1980[2] Av. temp.	1981[4] No. sets	1981[4] Av. catch	1981[4] Av. temp.	1979-81 No. sets	1979-81 Av. catch	1979-81 Av. temp.
1,2&3	221-260	-	-	-	-	-	-	2	0.3	0.7	2	0.3	0.7
(north)	261-300	1	0.1	3.0	1	6.8	3.0	-	-	-	2	3.5	3.0
	301-340	3	3.9	3.0	2	14.5	3.2	2	0.0	2.2	7	5.8	2.8
	341-380	3	17.3	2.6	3	25.4	2.9	-	-	-	6	21.4	2.8
	381-420	4	46.9	3.2	4	64.0	3.3	3	12.9	2.7	11	43.9	3.1
	421-460	3	59.6	3.1	3	27.1	3.2	2	3.3	3.3	8	33.3	3.2
	461-500	3	53.5	3.1	3	28.3	3.3	4	1.5	3.0	10	25.1	3.1
	501-540	2	37.9	3.1	4	10.4	3.5	4	0.3	3.1	10	11.9	3.3
	>540		-	-	2	3.9	3.5		-	-	2	3.9	3.5
4,5&6	221-260	-	-	-	-	-	-	2	0.0	1.7	2	0.0	1.7
(south)	261-300	-	-	-	-	-	-		-	-	-	-	-
	301-340	-	-	-	-	-	-	2	1.0	2.0	2	1.0	2.0
	341-380	1	28.6	2.5	1	12.6	3.0	2	5.9	2.3	4	13.3	2.5
	381-420	1	45.4	2.9	1	8.2	3.3	2	21.0	2.6	4	23.9	2.9
	421-460	2	2.5	3.1	2	26.0	3.9	2	6.4	2.8	6	12.3	3.3
	461-500	1	27.2	3.1	2	20.9	3.3	3	3.0	3.2	6	13.0	3.2
	501-540	2	9.5	3.1	1	7.3	3.4	2	1.8	3.1	5	6.0	3.2

[1]See Fig. 2c.
[2]July 17-22
[3]July 30-Aug. 2
[4]July 8-11

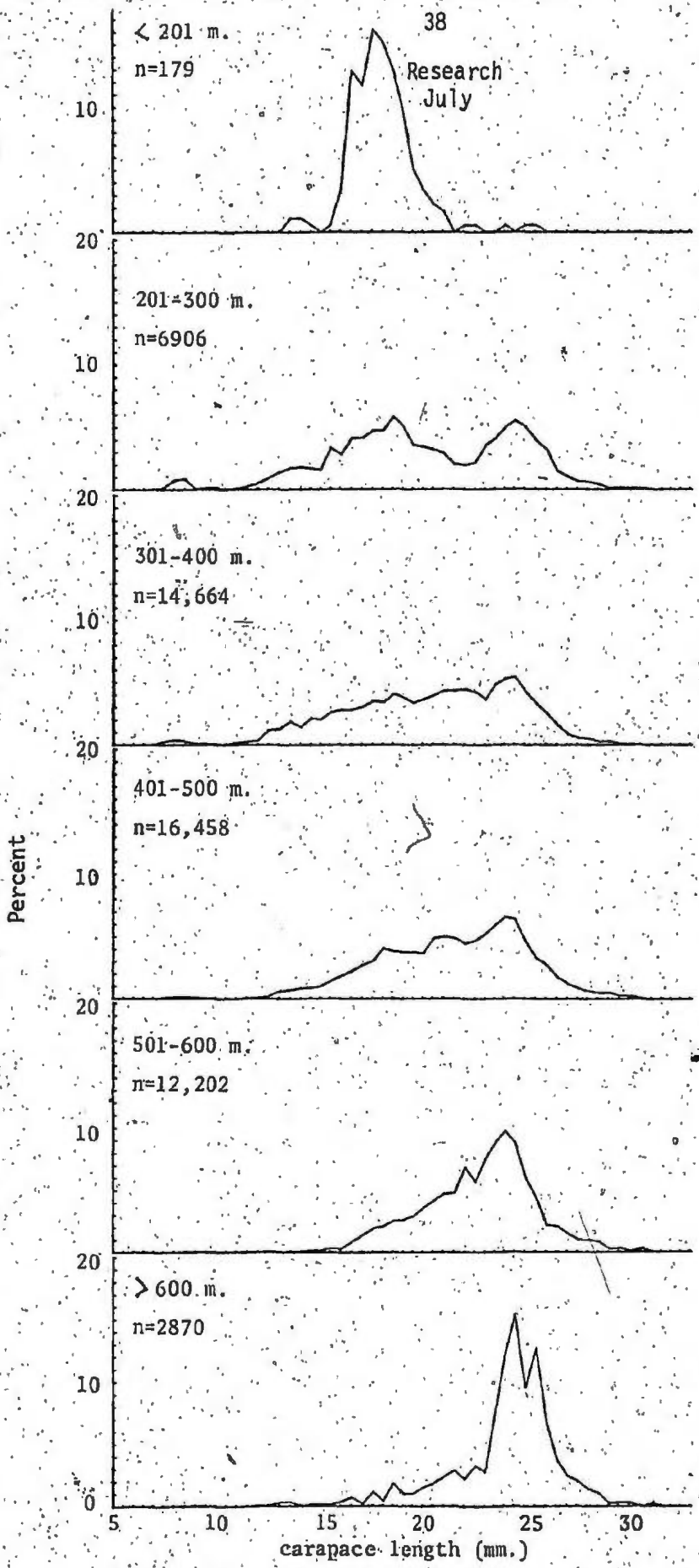


Fig.6a. Length distribution of P.borealis by depth - Hopedale Channel,1979-81.

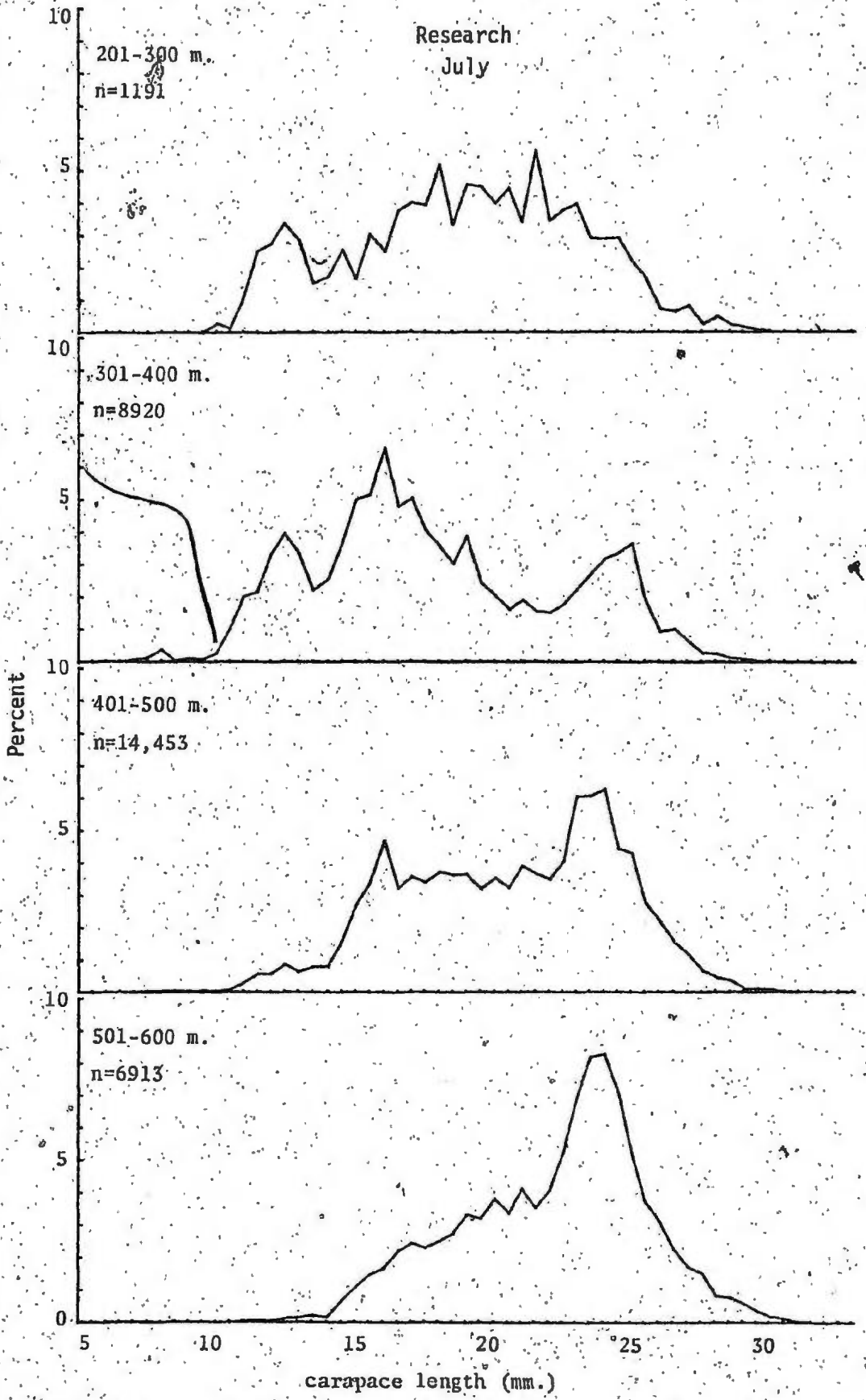


Fig.6b.Length distribution of P.borealis by depth - Cartwright Channel, 1979-81.

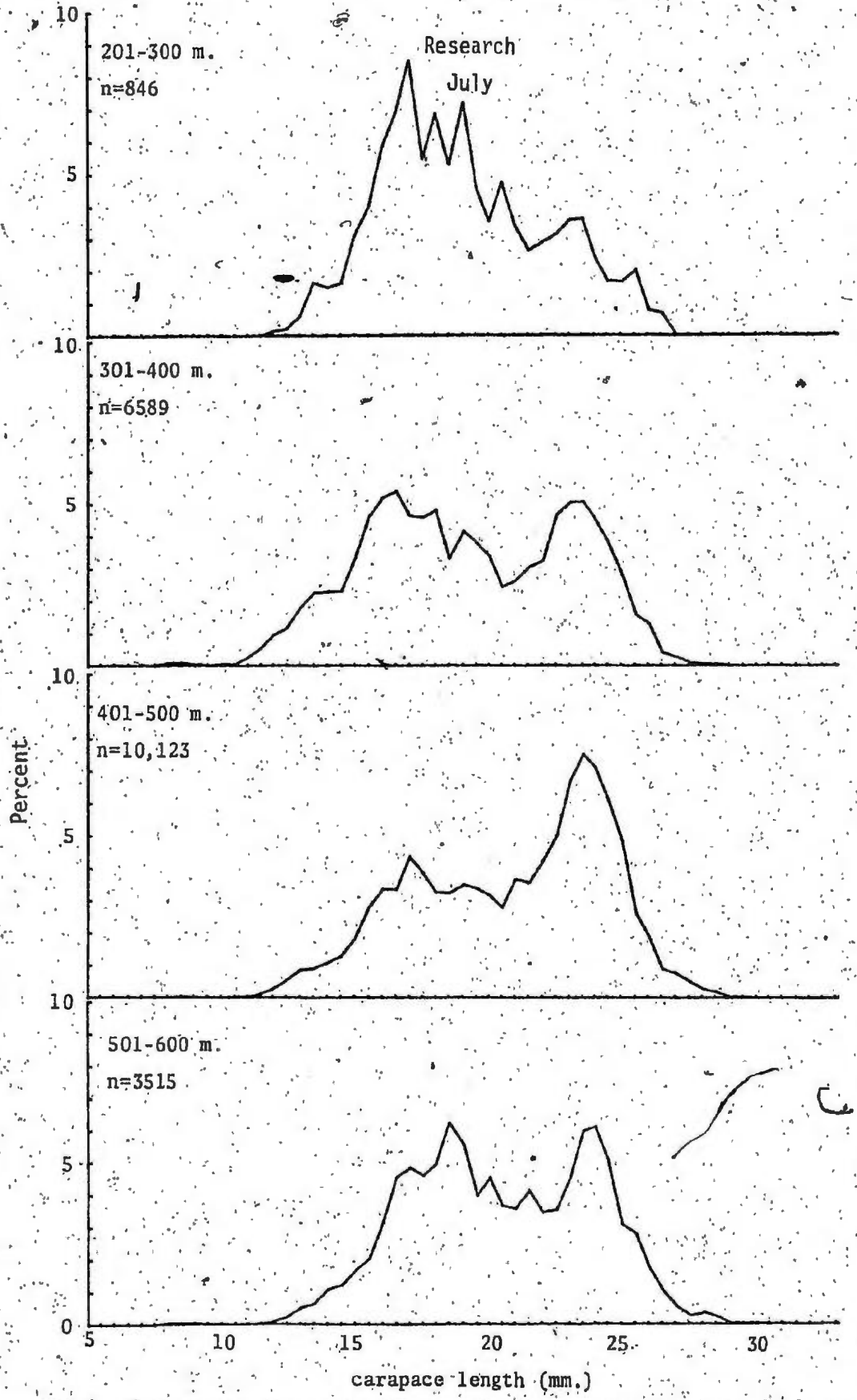


Fig.6c. Length distribution of P.borealis by depth - Hawke Channel,1979-81.

increasing mean size with depth. The deepest water was again dominated by large female shrimp. The sampling of shrimp length by depth in the Hawke Channel suggested the same general trend as in the two other areas (Fig. 6c). However, the deepest depth interval (501-600 m) did not show the dominance of females.

C. Diel Variability

Plots of catch per standard tow against time (expressed over a 24-hour period) are given in Fig. 7. In 1980, shrimp were concentrated in deep water and catches from depths around 550 m were low (< 100 kg) from 2000 to 1200 hours NST (Fig. 7a). Best catches were obtained between 1300 and 1900 hours but remained variable. In the following year, highest concentrations occurred in shallower water and catches from 350 m were consistently low (< 100 kg) from 1500 to 0400 hours but increased during the morning and remained high until the early afternoon (Fig. 7b). Peaks were interpreted in the data between 1500 and 1800 hours in 1980 and between 0800 and 1000 hours in 1981.

Weighted average lengths of shrimp in the catches were plotted against time for both years (Fig. 8). Small shrimp were more abundant in the catch during midday in both years. The average length increased during the afternoon reaching a peak around midnight and then decreased during the early morning. Relationships between average length of shrimp in the catch and catch (kg) per standard tow were not apparent (Fig. 9).

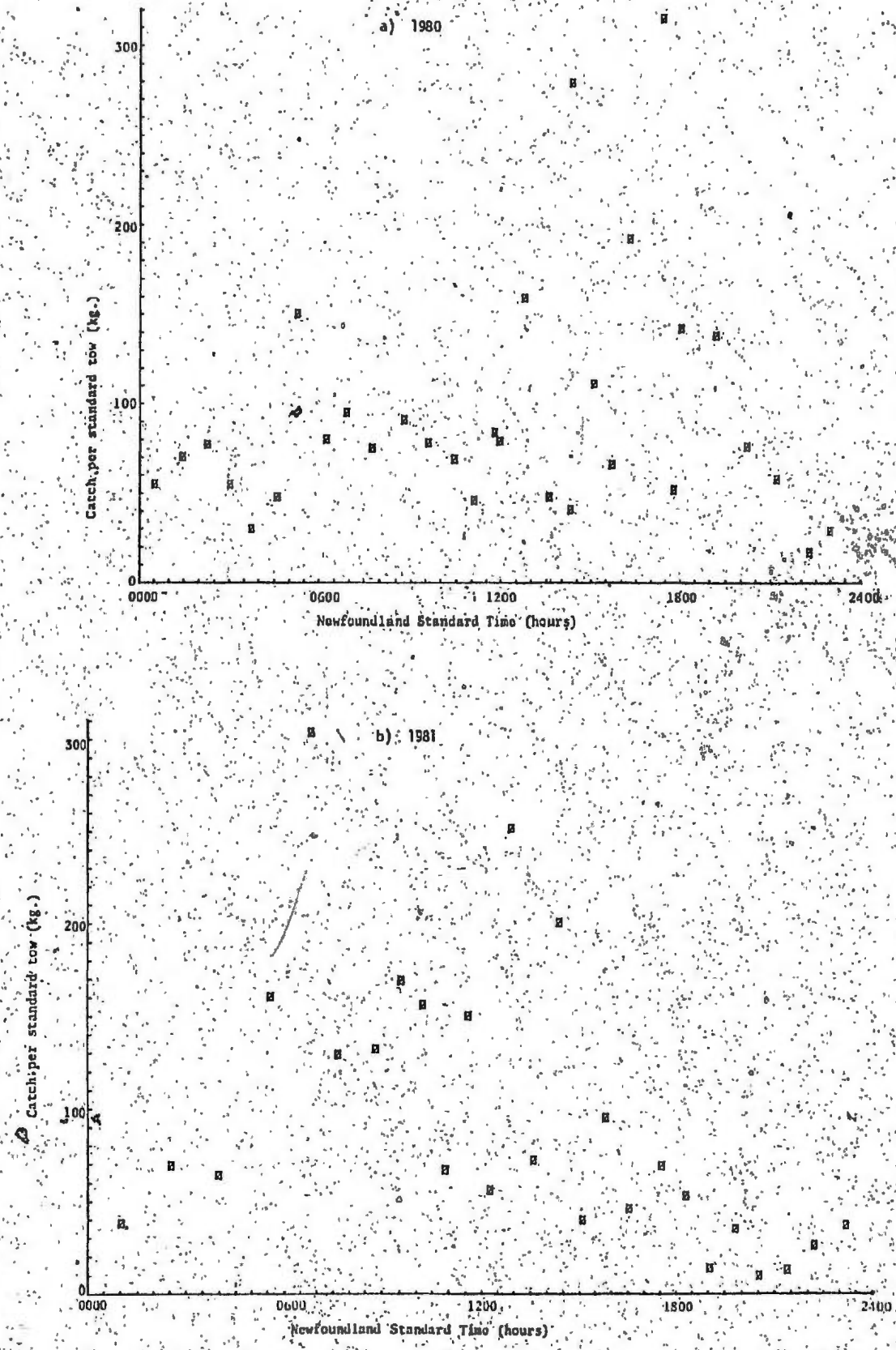


Fig.7. Diel variability in shrimp catches - Hopedale Channel, July 27-29,1980 and July 25-26,1981.

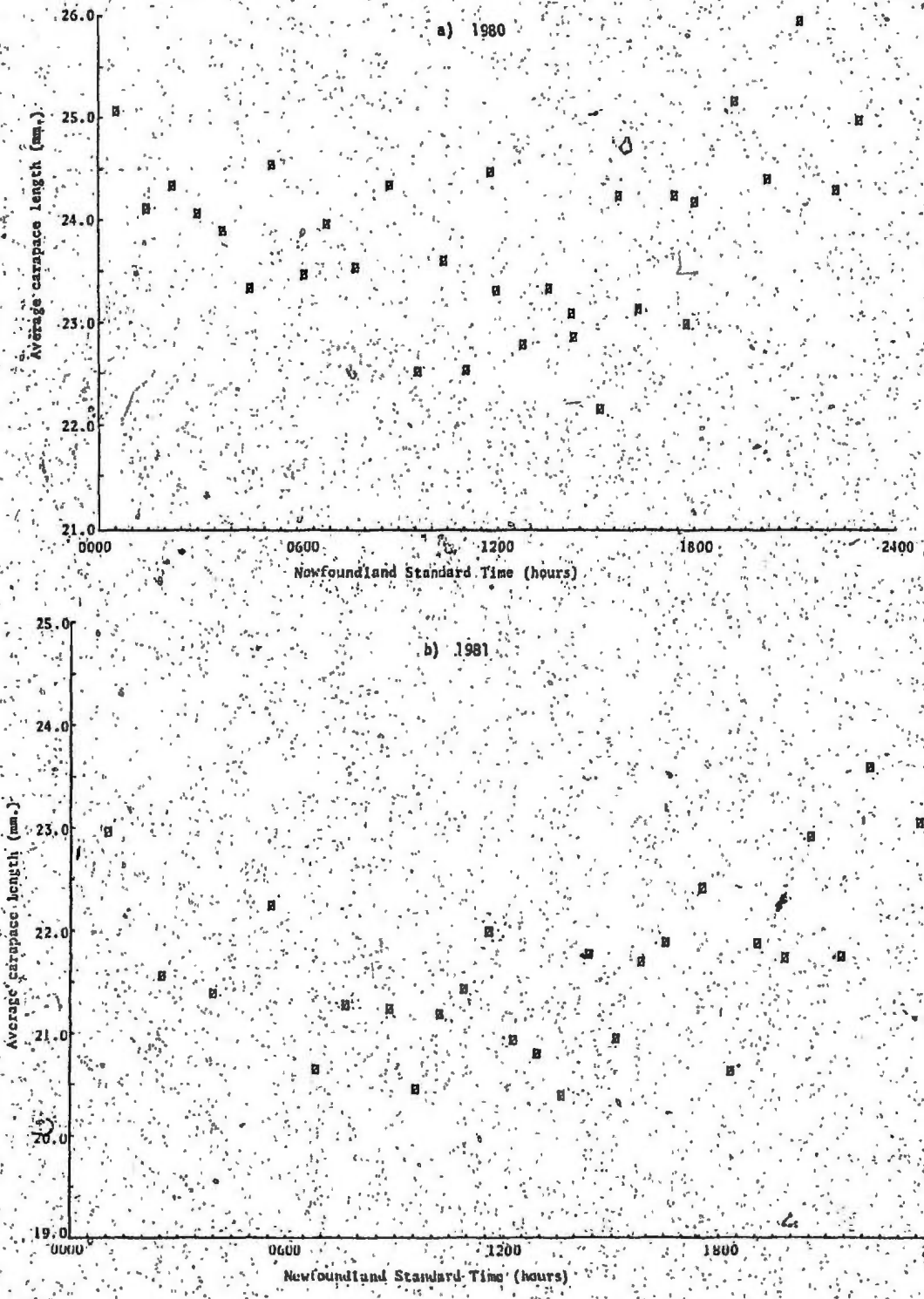


Fig.8. Diel changes in average shrimp length - Hopedale Channel, July 27-29,1980 and July 25-26,1981.

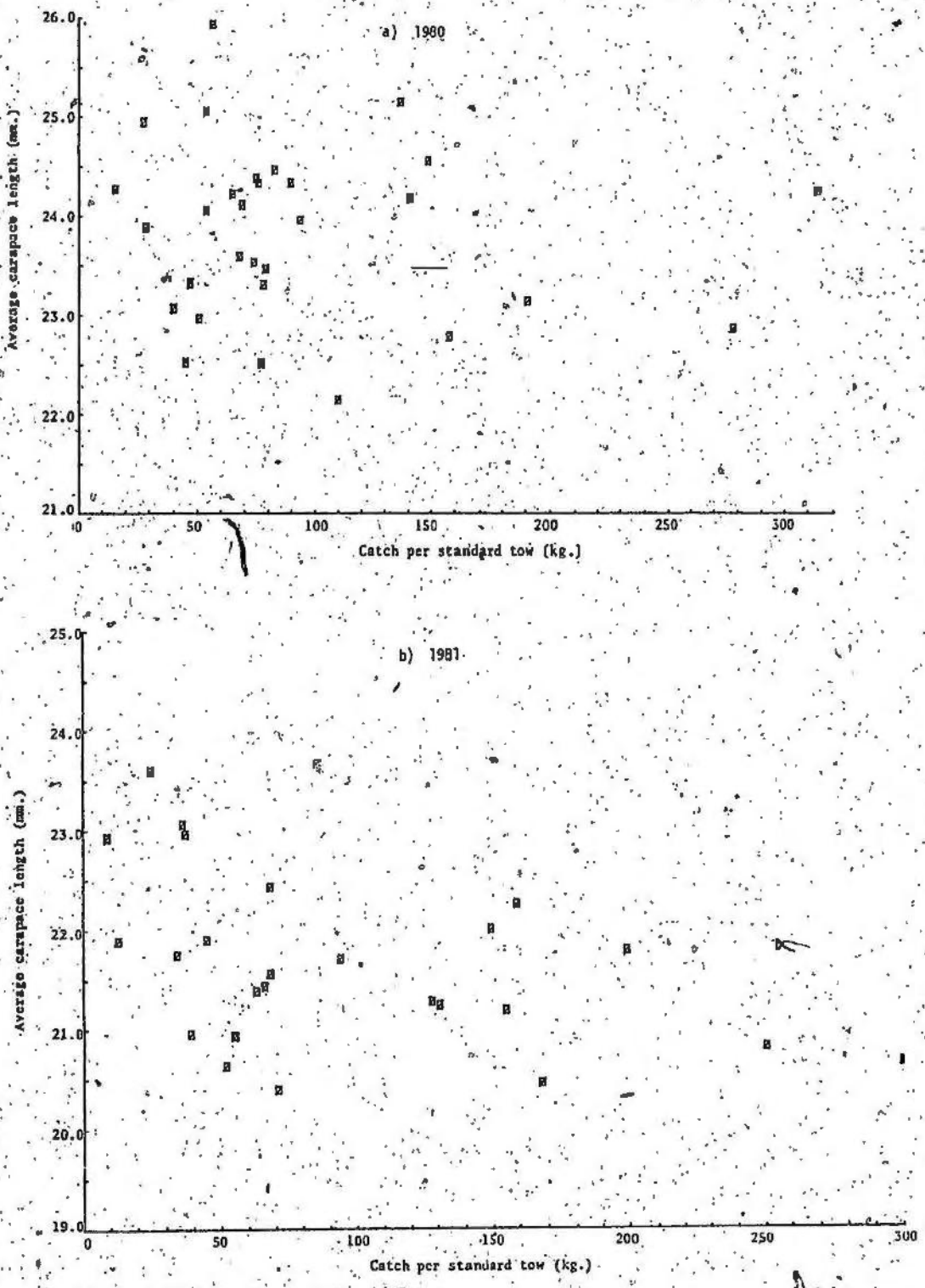


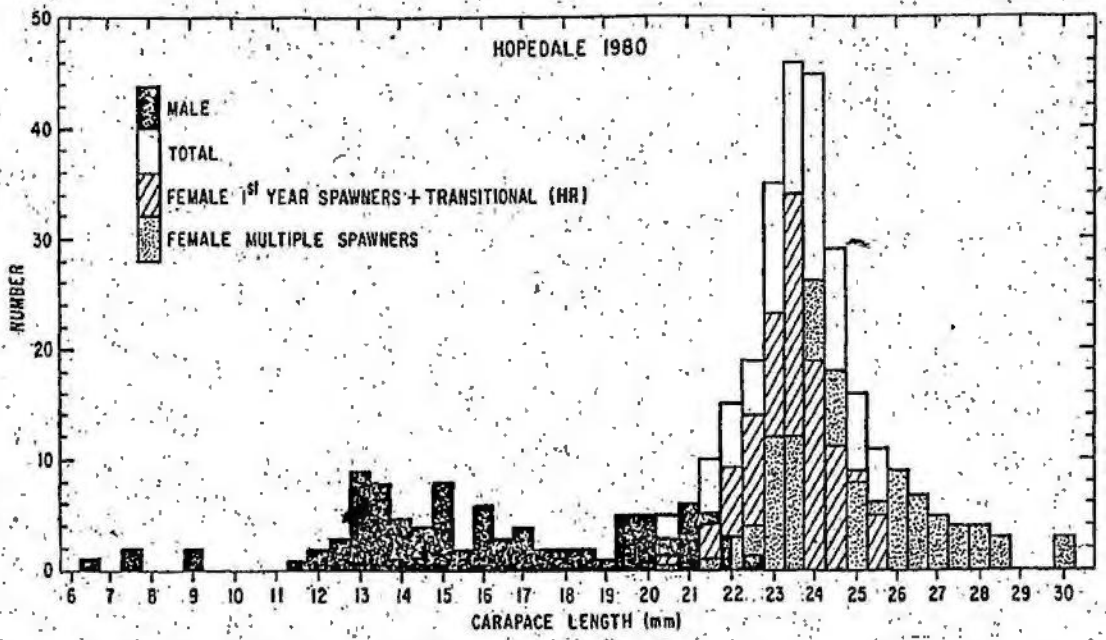
Fig.9. Relationship between average shrimp length and catch per standard tow - Hopedale Channel, July 27-29,1980 and July 25-26,1981.

Sex and Maturity

Sex and maturity data are available for the Hopedale and Cartwright channels and are shown in Fig. 10. Males up to 21.5 and 22.5, inclusive, were present in these channels. In both samples taken in mid-July, first-year females were relatively rare, numbering 15 in the Hopedale sample and 21 in the Cartwright sample, while transitional animals of similar size numbered 114 and 44, respectively (Table 4). Virtually all members of both groups possessed ovaries in advanced stages of development. One transitional animal from each sample showed no evidence of ripening ovaries. Both stages appeared to belong to the same modal length group in each channel and were consequently combined. Females spawning again (those without sternal spines or possessing only remnants) formed an obvious mode to the right of the first-year females. Additional modes of multiple spawners were also apparent. All individuals of multiple spawners possessed matured ovaries in the Cartwright Channel while in the Hopedale Channel seven were without.

The above samples were used to construct ogives, useful in determining differences in sexual development between samples from each channel. Additional samples were added to increase sample size at critical lengths. The Hopedale sample then contained 597 animals and the Cartwright, 629. Figure 11 shows the decline in proportion of males with increasing length for both channels. Males comprised approximately 50% of the individuals in the 21.5 mm length interval in both samples.

Similar data were obtained from the 1978 research survey from all three channels. Figure 12 shows the relationship between the



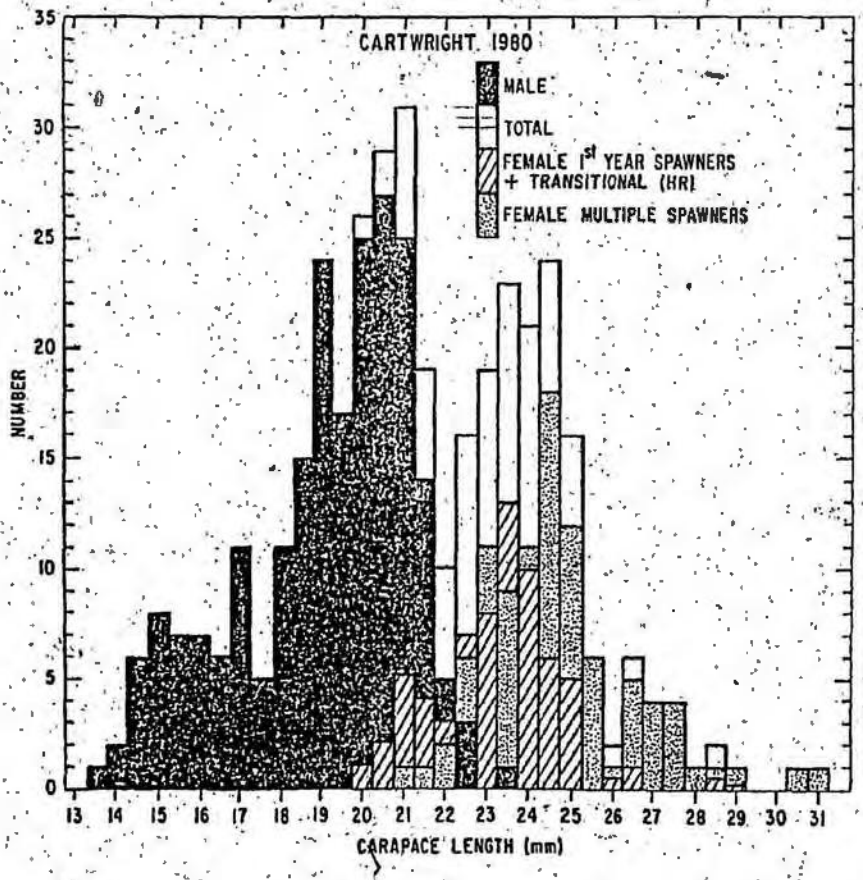


Fig.10. Shrimp sex and maturity - Hopedale and Cartwright channels,1980. (July 14 and 18, respectively.)

Table 4. Sex and maturity stages of shrimp from two Labrador Channels.

Details of shrimp sample, Hopedale Channel, July 1980.

Length	Males	Transitionals	Females with sternal spines	Females without sternal spines	Total
6.5	1				1
7.0	0				0
	2				2
8.0	0				0
	0				0
9.0	2				2
	0				0
10.0	0				0
	0				0
11.0	0				0
	1				1
12.0	2				2
	3				3
13.0	9				9
	8				8
14.0	5				5
	4				4
15.0	8				8
	2				2
16.0	6				6
	3				3
17.0	4				4
	2				2
18.0	2				2
	2				2
19.0	1				1
	5				5
20.0	5				5
	3	1		1	5
21.0	6	0		0	6
	5	4		1	10
22.0	3	8	1	3	15
	1	14	0	4	19
23.0		23	0	12	35
		29	5	12	46
24.0		17	2	26	45
		10	1	18	29
25.0		7	2	8	17
		1	4	6	11
26.0				9	9
				7	7
27.0				5	5
				4	4
28.0				4	4
				3	3
29.0				0	0
				0	0
30.0				3	3
Totals	95	114	15	126	350

Details of shrimp sample, Cartwright Channel, July 1980

Length	Males	Transitionals	Females with sternal spines	Females without sternal spines	Total
13.0					
	1				1
14.0	2				2
	6				6
15.0	8				8
	7				7
16.0	7				7
	6				6
17.0	11				11
	5				5
18.0	11				11
	15				15
19.0	24				24
	17				17
20.0	25	1			26
	27	2			29
21.0	25	4	1	1	31
	13	5	0	1	19
22.0	5	3	0	2	10
	3	5	2	6	16
23.0	0	5	3	11	19
	1	10	3	9	23
24.0		4	6	11	21
		1	5	18	24
25.0		3	1	12	16
		0		6	6
26.0				5	5
27.0				4	4
				4	4
28.0				1	1
				1	1
29.0					
30.0				1	1
				1	1
Totals	219	44	21	96	380

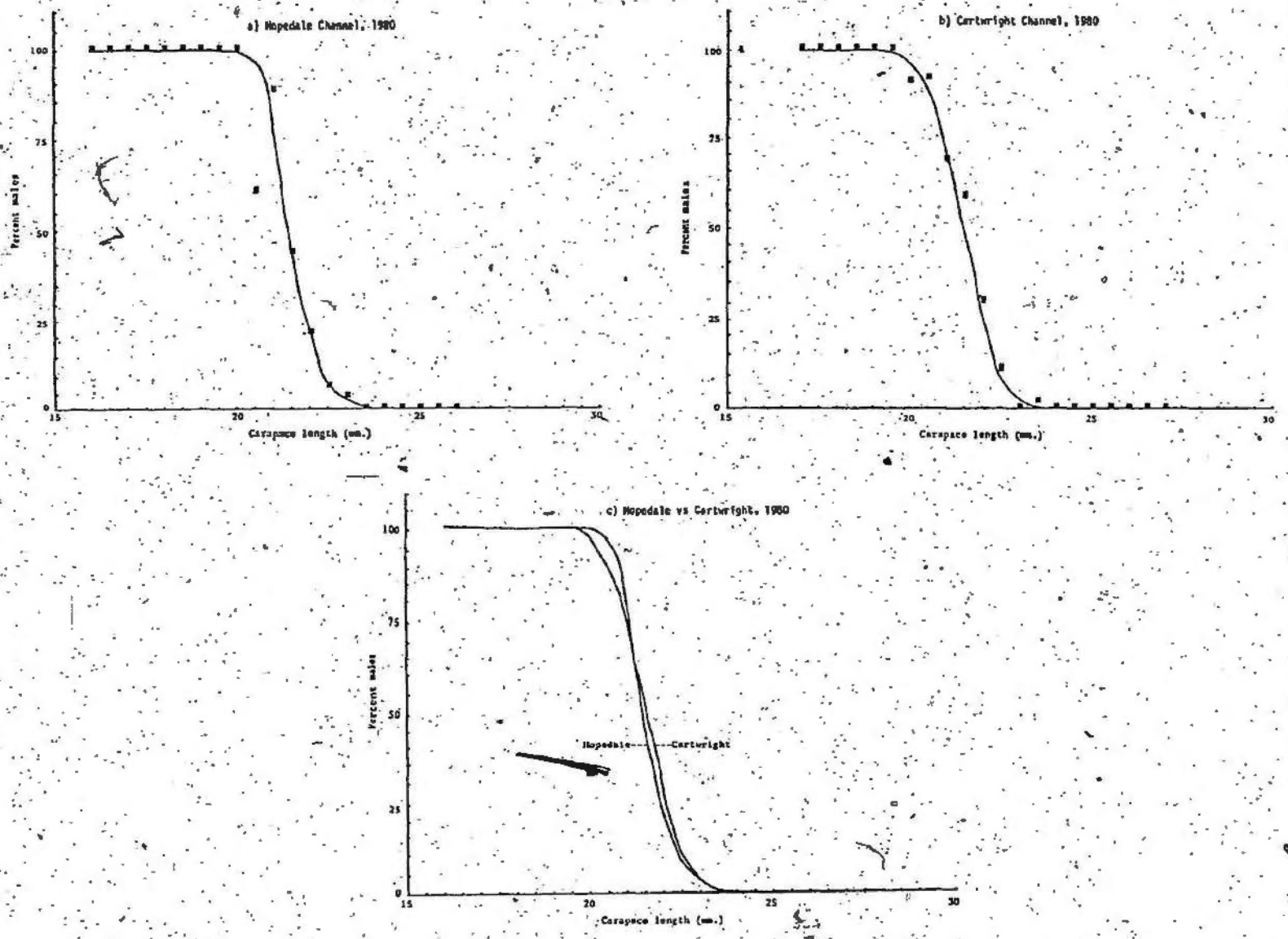


Fig.11. Percent male shrimp versus carapace length - Hopedale and Cartwright Channels, 1980. (July 14 and 18, respectively.)

proportion of non-ovigerous animals and carapace length. The non-ovigerous animals (on the left of the curve) include immature and adult males. The data were also interpreted to reflect differences in sexual development between samples from each channel. In 1978 sex reversal apparently occurred in smaller animals in the Cartwright Channel than in the other two areas (Fig. 12d). There was also a greater proportion of non-ovigerous females in the Cartwright Channel as indicated in Fig. 12b (to the right). Results from Hawke Channel (Fig. 12c) were similar to those from Hopedale (Fig. 12a) with the exception that a small proportion of the smaller animals were ovigerous.

A comparison of samples within channels showed some decrease in size at sex reversal between 1978 and 1980. The decrease was relatively pronounced in the Hopedale Channel (Fig. 13a) with 50% males occurring at 22.0 mm in 1978 and 21.5 mm in 1980. The decrease was only slight in the Cartwright Channel with 50% males occurring at 21.75 and 21.5 mm carapace length in the two years, respectively (Fig. 13b).

Weight-Length Relationships

Weight-length curves for the data from each of the three areas are given in Fig. 14a, b, and c and a comparison is made in Fig. 14d. The equations for these curves are:

$$w = 0.00053420\ell^{3.0755}$$

for Hopedale Channel

$$w = 0.00080244\ell^{2.9307}$$

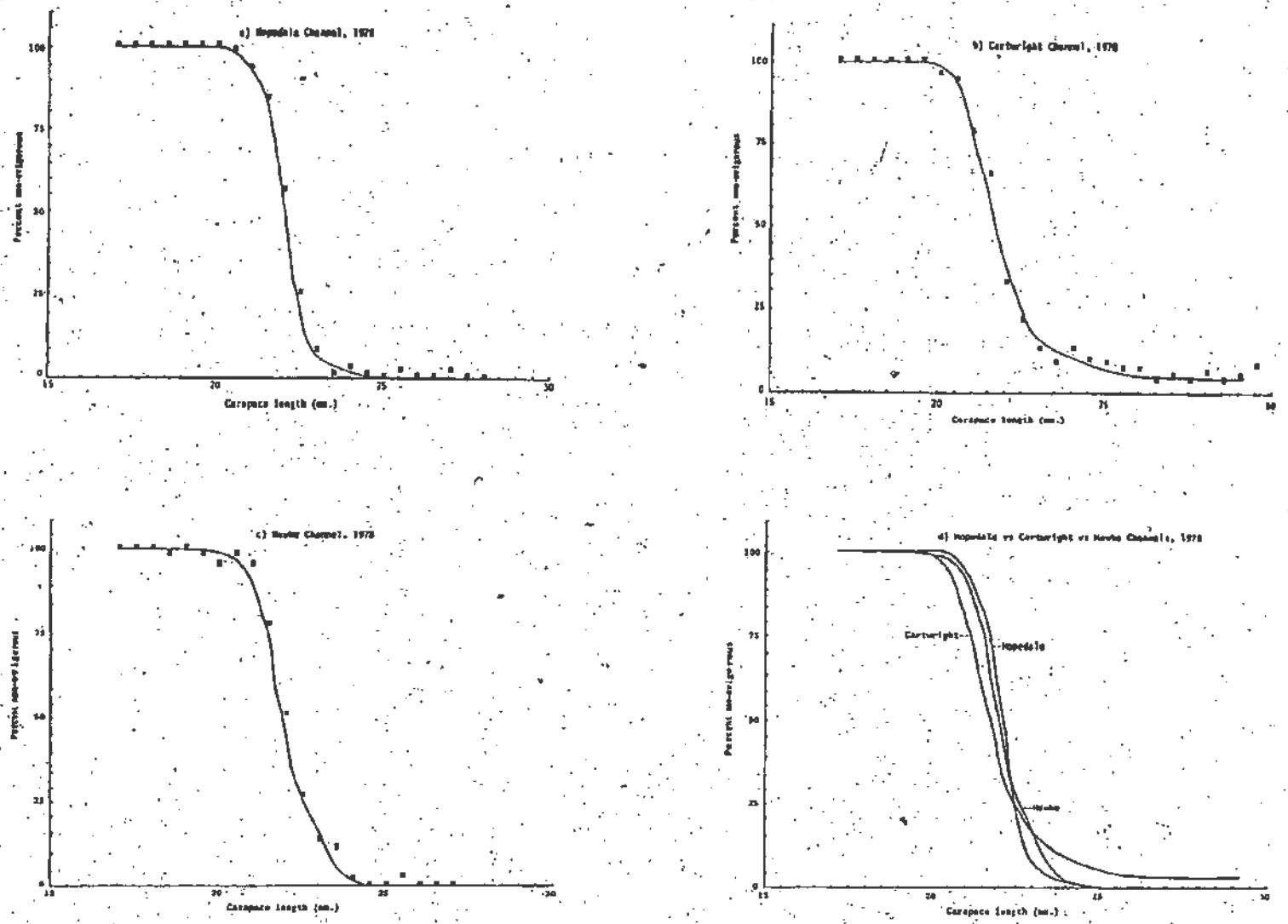
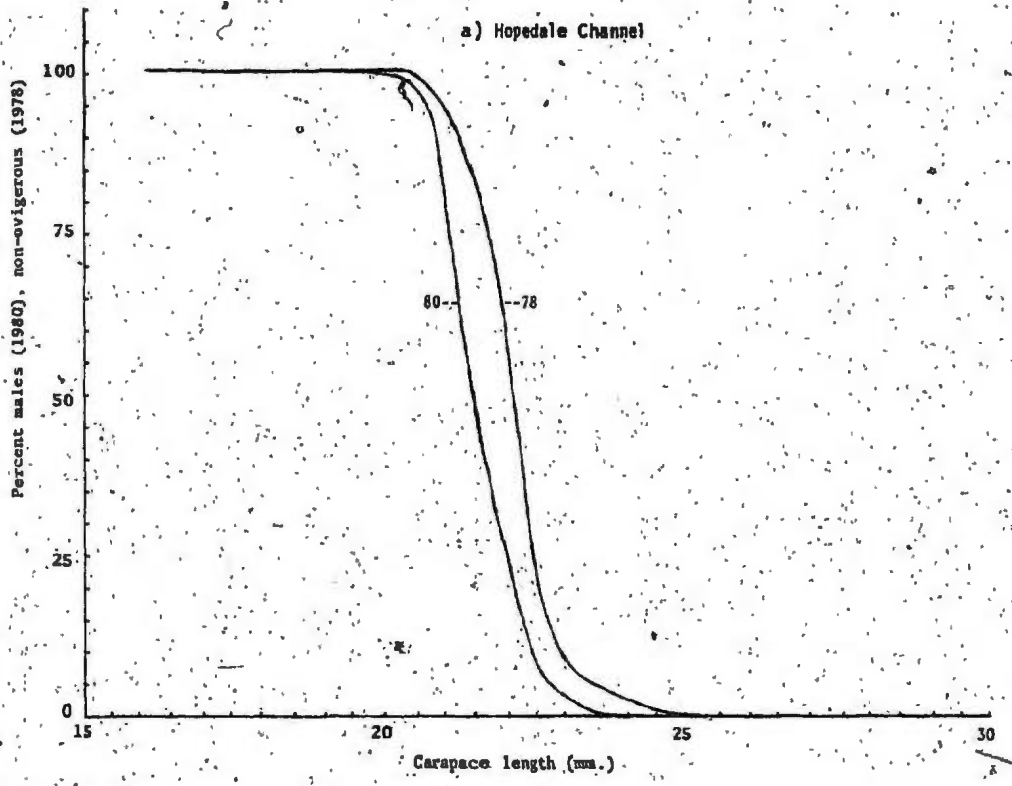


Fig.12. Percent non-ovigerous shrimp versus carapace length - Hopedale (Sept.25-28), Cartwright (Sept.19-24) and Hawke (Oct.1) channels,1978.



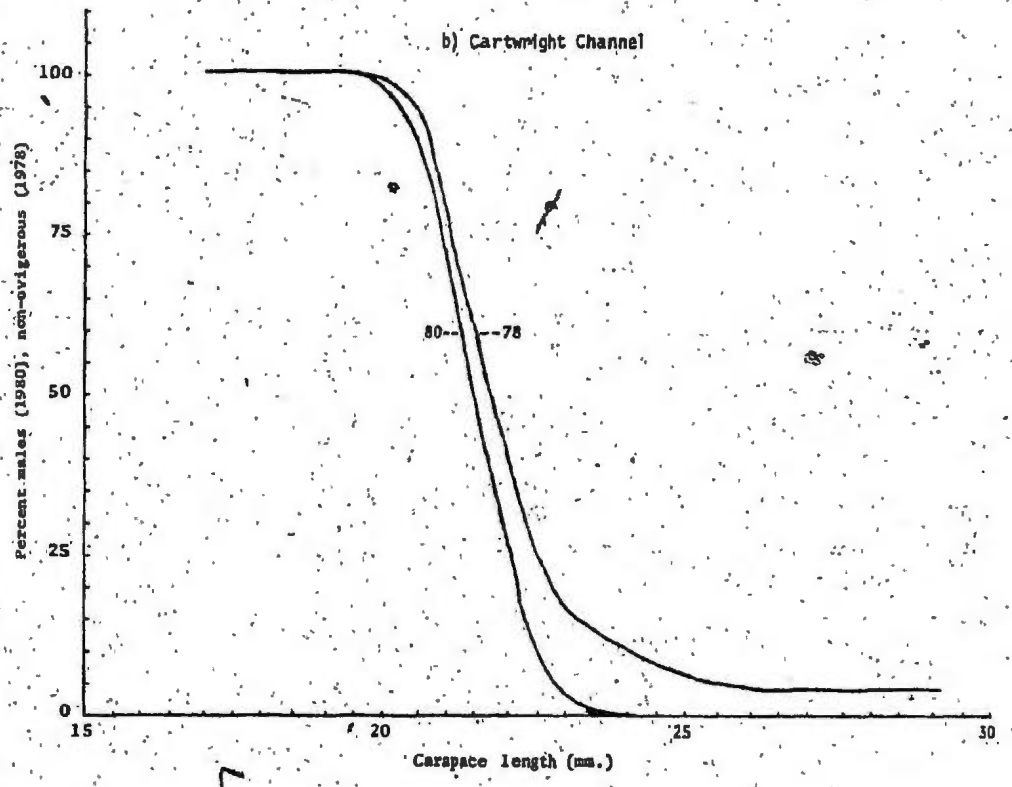
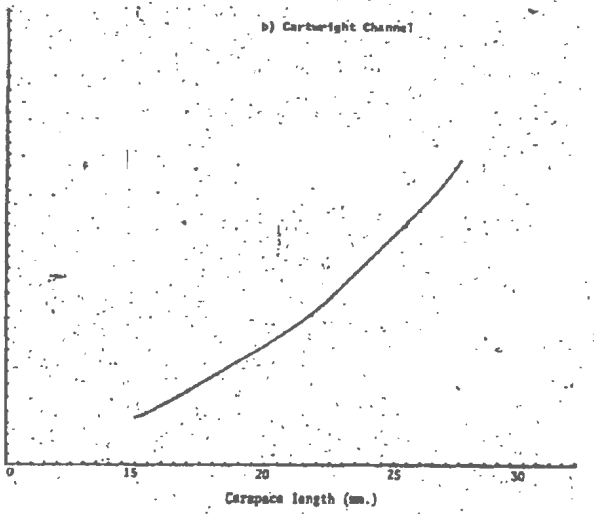
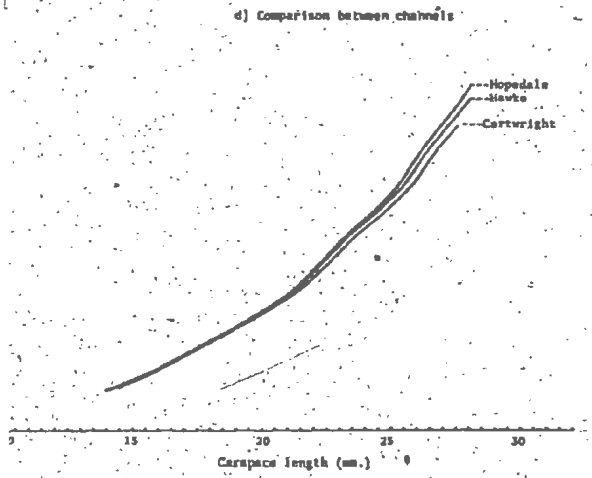


Fig.13. Comparison of shrimp maturity ogives within channels and between years, 1978 vs 1980.





wright and Hawke Channels, 1979.

for Cartwright Channel

$$w = 0.00074907\ell^{2.9634}$$

for Hawke Channel.

Correlation coefficients (r) in all areas were greater than 0.99. Exponents were very close to 3 and indicated isometric growth which has been described by Ricker (1975) as characteristic of fish that demonstrate unchanging body form and unchanging specific gravity. However, t-tests showed that in the samples from the Hopedale and Cartwright Channels the exponents were significantly different from 3 ($P < 0.005$) while in the Hawke Channel sample there was no statistical difference ($0.10 < P < 0.20$).

Analyses of covariance (summarized in Table 5) on pairs of log-log relationships indicated significant differences in slopes between samples from Hopedale and Cartwright Channels and Hopedale and Hawke Channels ($P \leq 0.001$). Slopes for Cartwright and Hawke Channels were similar ($P = 0.30$) but adjusted means were significantly different ($P << 0.001$).

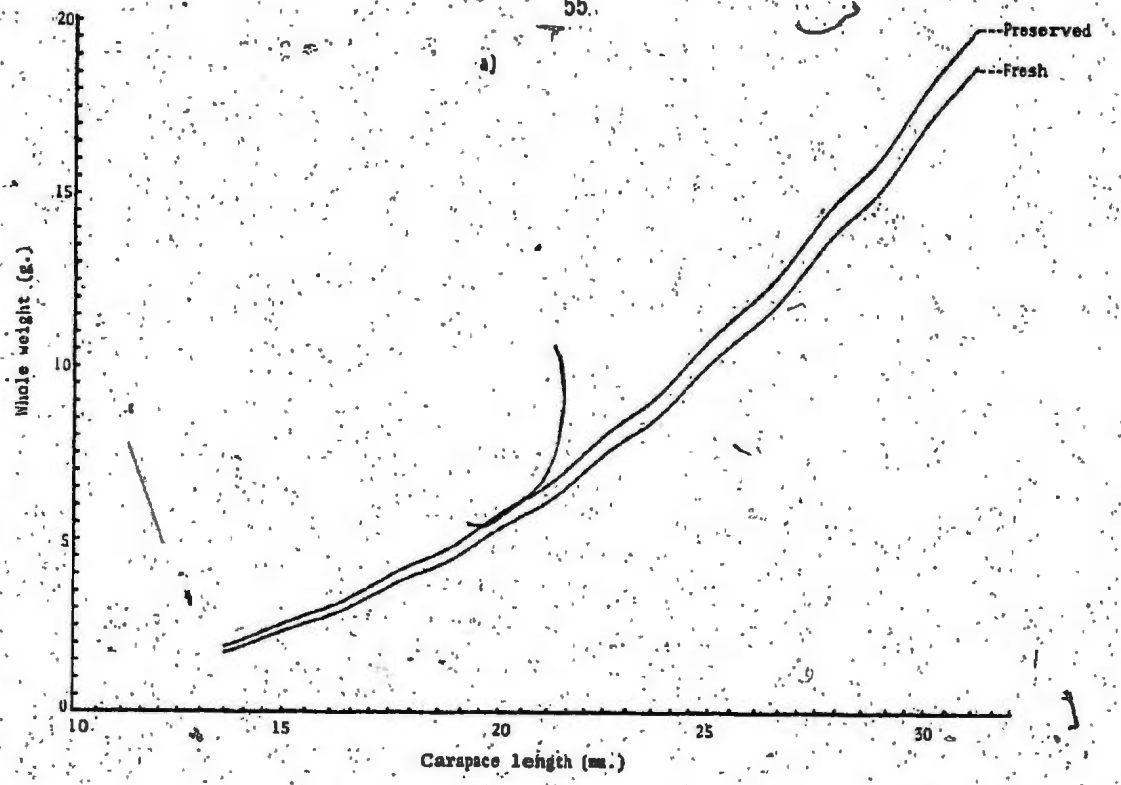
A comparison of fresh vs. preserved weight is given in Fig. 15a. Comparisons of weight-length equations with shrimp stocks in other parts of the world are given in Table 6 and Fig. 15b.

Fecundity

The general relationship for all data is given in Fig. 16. The data base contained a number of possible sources of variation which included area (Hopedale, Cartwright and Hawke Channels), season (Hopedale - August and November, 1977; Hawke August and November-December, 1974) and year (Hopedale, 1977 and 1978, and

Table 5. Summary of analysis of covariance on weight-length relationships for shrimp samples from the Hopedale, Cartwright and Hawke Channel.

Comparisons	Residual Mean squares F	P	Slopes F	P	Means F	P
Hopedale vs. Cartwright	1.02	>0.50	20.65	0.000		
Hopedale vs. Hawke	1.09	>0.20	12.14	0.001		
Cartwright vs. Hawke	1.12	>0.20	1.09	0.297	40.79	0.000



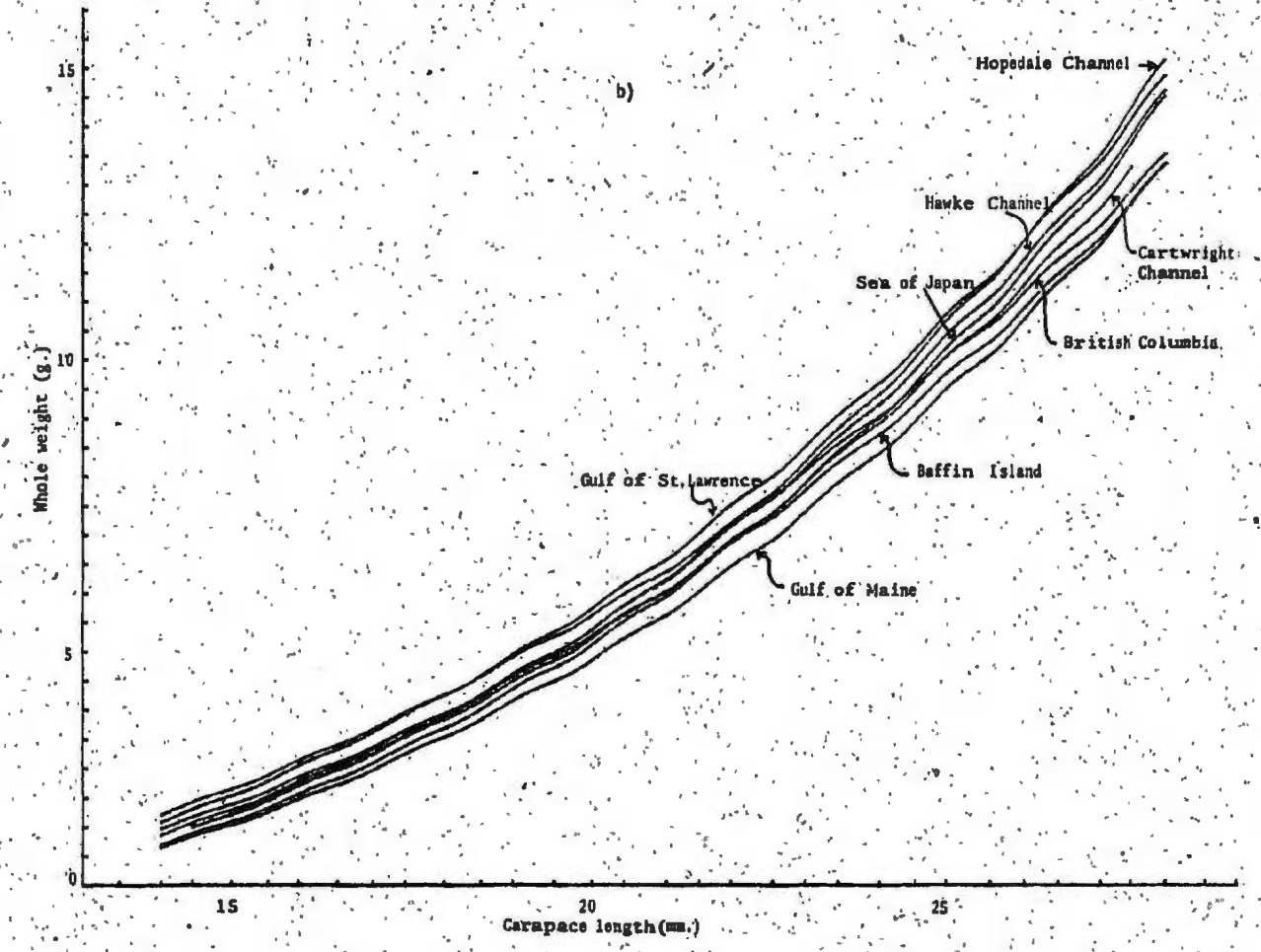


Fig.15. Comparison between preserved and fresh weights of shrimp from the Gulf of St.Lawrence (a) and weight - length curves for P. borealis from other areas (b).

Table 6. Comparison of weight-length relationships for shrimp (Pandalus borealis) from various areas in the Northern Hemisphere.

Reference	Area	Equation	Notes
Haynes & Wigley (1969)	Gulf of Maine	$w = 0.00059307l^{3.007}$	fresh
Minet et al. (1977)	SA 0 (Baffin)	$w = 0.00136309l^{2.757}$	?
Ito (1976)	Sea of Japan	$w = 0.00048128l^{3.0942}$	males and transitionals, fresh
Butler (1964)	British Columbia	$w = 0.00225460l^{2.60977}$	fresh
Parsons (this paper)	Esquiman Channel	$w = 0.00121895l^{2.8227}$	preserved
Parsons (this paper)	Hopedale Channel	$w = 0.00053420l^{3.0755}$	preserved
Parsons (this paper)	Cartwright Channel	$w = 0.00080244l^{2.9307}$	preserved
Parsons (this paper)	Hawke Channel	$w = 0.00074907l^{2.9634}$	preserved

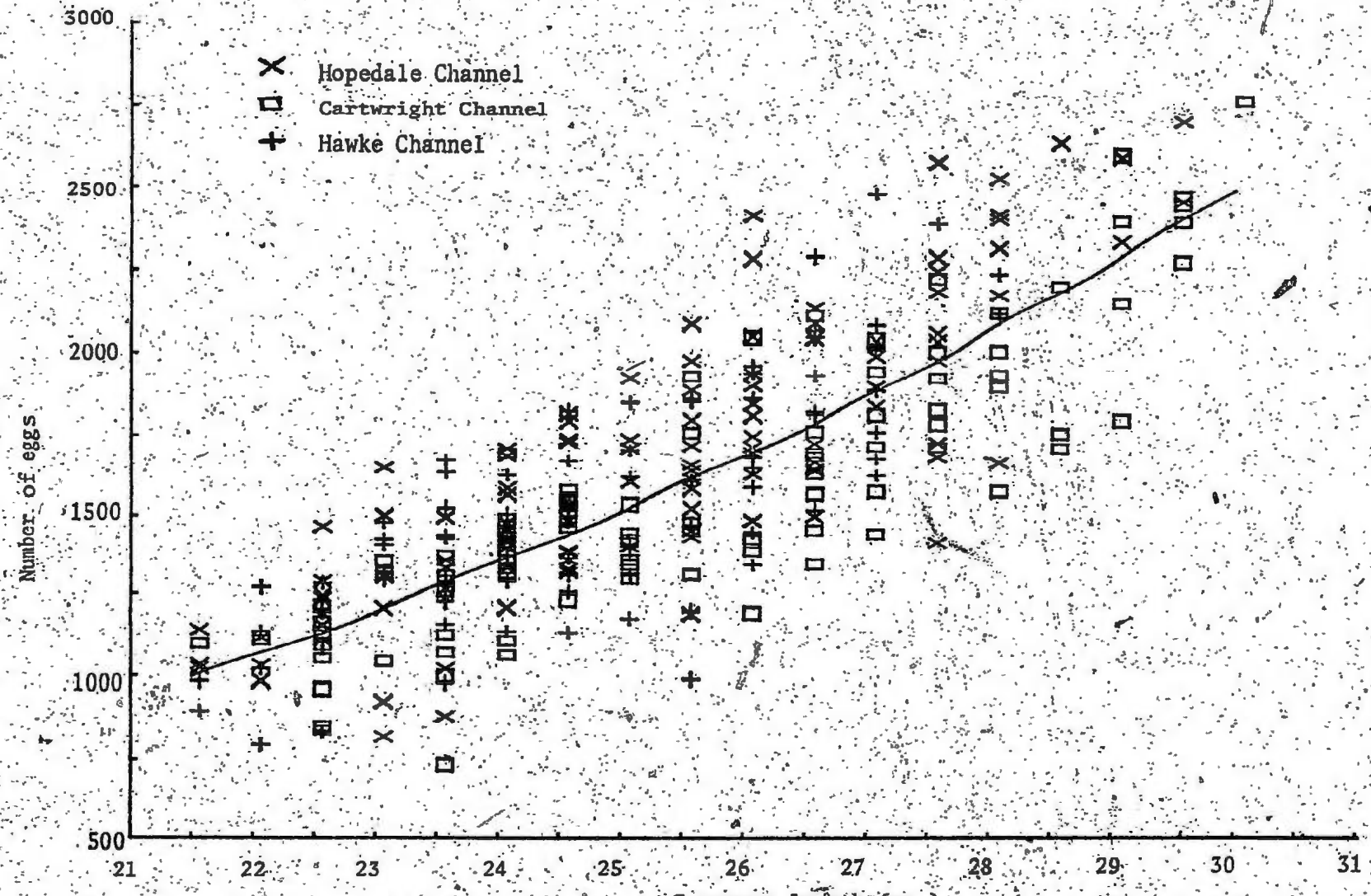


Fig.16. Fecundity of Pandalus borealis in Hopedale, Cartwright and Hawke Channels.

Hawke 1974, 1975, and 1977). Therefore, in addition to pooling all data, relationships are given for the components which represent seasons and years (Table 7). Although fecundity-at-length shows considerable variation, all r values are significantly different from zero ($P << 0.01$).

Analyses of covariance were performed on log-log transformed data between channels using all samples (Fig. 17a), between seasons in the same year for Hopedale (Fig. 17b) and Hawke Channels (Fig. 17c) and between years (1974, 1975, and 1977 Fig. 17d) in Hawke Channel and (1977 and 1978, Fig. 17e) in Hopedale Channel. Each comparison was tested for homogeneity of variance (Tables 8 and 9). The initial comparison of all data between channels indicated similarity in slopes but highly significant differences in adjusted means (Table 8). Subsequent t-tests for adjusted means (Table 10) indicated similarity between samples from Hopedale and Hawke Channels but highly significant differences between Cartwright and Hopedale, and Cartwright and Hawke Channels. Mean number of eggs over a comparable size range was lowest in samples from the Cartwright Channel.

Data from both the Hopedale and Hawke Channels showed significant differences between samples taken in different seasons of the same year. In fact, the samples from Hawke Channel in 1974 showed heteroscedasticity.

No significant differences were apparent between years for either the Hopedale or Hawke Channels.

In light of the above findings, the comparison between channels was revised (Fig. 17f), eliminating late season data (i.e., November). Conclusions resulting from this comparison were the same as those from the initial run (Table 10).

Table 7. Regression equations for fecundity (number of eggs) against carapace length (mm.) for shrimp in the Labrador channels.

Sample	N	Equation	r
All data	294	$F = 0.2195L^{2.7448}$	0.83
Hopedale (all data)	117	$F = 0.1670L^{2.8416}$	0.84
Cartwright (all data)	90	$F = 0.1834L^{2.7804}$	0.86
Hawke (all data)	87	$F = 0.1649L^{2.8385}$	0.80
Hopedale (Aug. 77)	24	$F = 3.5834L^{1.8809}$	0.67
(Nov. 77)	47	$F = 0.0312L^{3.3527}$	0.90
(Sept. 78)	46	$F = 0.2084L^{2.7814}$	0.85
Hawke (Aug. 74)	20	$F = 0.0573L^{3.1620}$	0.80
(Nov.-Dec. 74)	23	$F = 8.9316L^{1.5789}$	0.74
(Sept. 75)	27	$F = 0.1034L^{2.9932}$	0.82
(Aug. 77)	17	$F = 0.0891L^{3.0466}$	0.84
Hopedale (Aug. 77 & Sept. 78)	70	$F = 0.4236L^{2.5560}$	0.80
Cartwright (Sept. 78)	44	$F = 0.1244L^{2.9116}$	0.88
Hawke (Aug. 74, 75, & 77)	64	$F = 0.0566L^{3.1780}$	0.84

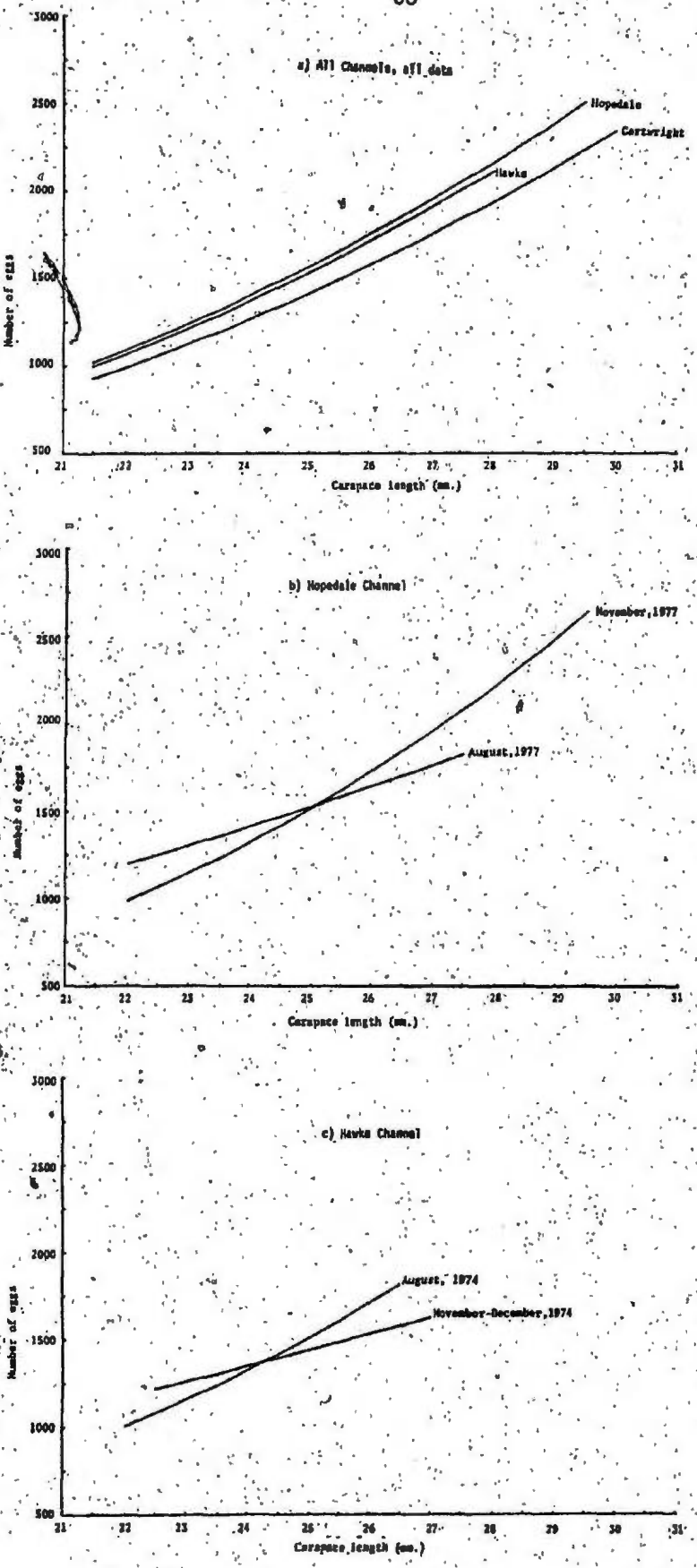
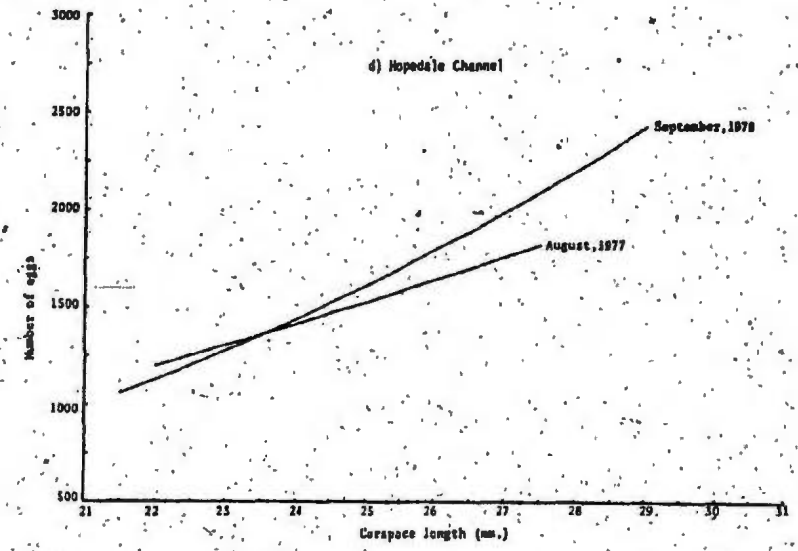
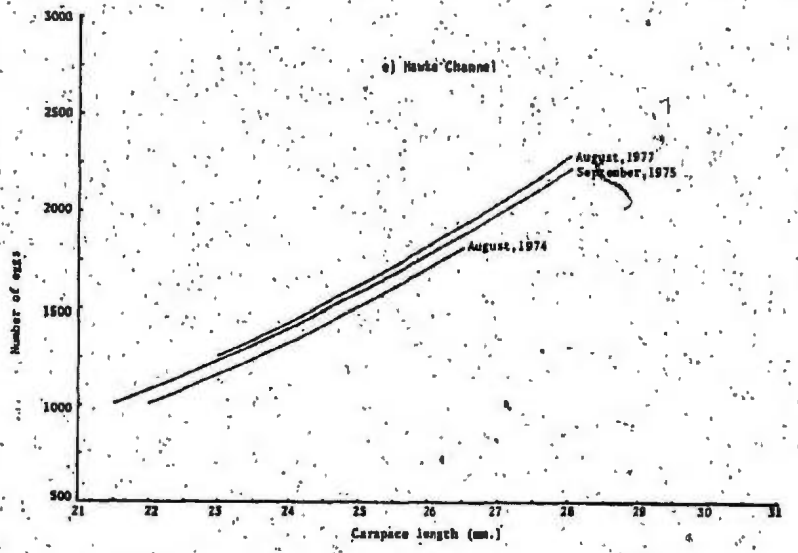


Fig.17. Comparisons of shrimp fecundity between channels, years and seasons.


d) Hopedale Channel
September, 1978
August, 1977
Number of eggs
Carapace length (mm.)


e) Hawke Channel
August, 1977
September, 1975
August, 1974
Number of eggs
Carapace length (mm.)

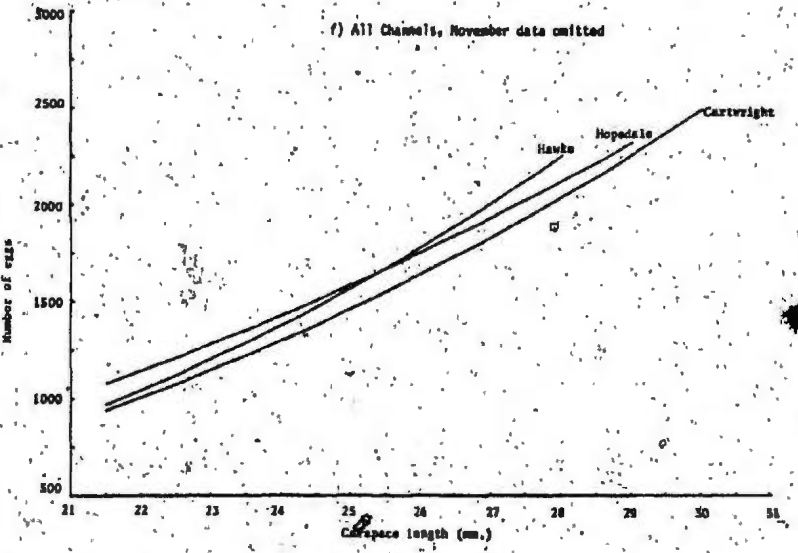

f) All Channels, November data omitted
Cartwright
Hopedale
Hawke
Number of eggs
Carapace length (mm.)

Fig. 17. (cont'd.)

Table 8. Summary of analysis of covariance on fecundity-length relationships for shrimp in three Labrador channels.

	Residual mean squares		Slopes		Means	
	[F or x^2][1]	P	F	P	F	P
Hopedale vs Cartwright vs Hawke (all data)	0.037	> 0.975	0.036	0.964	14.934	0.000
Hopedale (Aug. 77) vs Hopedale (Nov. 77)	1.233	> 0.500	9.102	0.004		
Hawke (Aug. 74) vs Hawke (Nov.-Dec. 74)	2.857	< 0.050				
Hawke (Aug. 74) vs Hawke 75 vs Hawke 77	0.787	> 0.500	0.031	0.970	1.286	0.284
Hopedale (Aug. 77) vs Hopedale (Sept. 78)	1.037	> 0.500	3.132	0.081	1.674	0.200
Hopedale vs Cartwright vs Hawke (Aug.-Sept., all years)	0.182	> 0.900	1.595	0.206	4.193	0.017

[1] Bartlett's Test (x^2) used for k > 2 (see Table9).

Table 9. Approximation of x^2 - Bartlett's test for homoscedasticity - for fecundity-length relationships for shrimp in three Labrador channels.

Sample	fi	Σ fi Si^2	Σfi log Si^2	M	C	x^2	v
Hopedale vs Cartwright vs Hawke (all data)	288	1.050	-702,2187	0.0373	1.0047	0.0371	2
Hawke (Aug. 74) vs Hawke 75 vs Hawke 77	58	0.235	-139.1068	0.8057	1.0242	0. 7867	2
Hopedale vs Cartwright vs Hawke (all years, Aug.-Sept.)	172	0.679	-413,5091	0.1837	1.0081	0.1822	2

Table 10. T-test for adjusted means comparing fecundity-length relationships for shrimp, between channels.

Comparisons		t	P
Hopedale vs Cartwright	All data	5.346	0.000
Hopedale vs Hawke	"	1.180	0.239
Cartwright vs Hawke	"	3.807	0.002
Hopedale vs Cartwright	All data (Aug.-Sept.)	2.856	0.005
Hopedale vs Hawke	"	0.725	0.470
Cartwright vs Hawke	"	2.143	0.034

Food and Feeding

Most stomachs observed (2461 or 64.87%) were empty, 1060 (27.94%) contained some food and 273 (7.20%) were considered to be full (Table 11). Food items of primary importance were mostly unidentifiable and were recorded as such in 62.04% (827) of stomachs with contents (1333). Contents of secondary and tertiary importance were more readily identifiable with 15.74 and 33.34% of observations, respectively, falling into the unidentified categories. Identifiable primary material occurred in stomachs in the following frequency: Crustacea were found in 304 stomachs (22.81%); sand (or mud) in 107 stomachs (8.03%); Polychaeta - 36 (2.70%); detritus - 36 (2.70%); and phytobenthos - 23 (1.73%). Items of secondary importance were recorded in 343 of the stomachs with contents: sand (or mud) in 204 stomachs (59.48%); Crustacea - 70 (20.41%); Polychaeta - 11 (3.21%); detritus - 3 (0.87%); Foraminifera - 1 (0.29%). Items of tertiary importance occurred rarely in only 36 stomachs. These were identified as sand (or mud) - 11 (30.56); Crustacea - 9 (25.00%); and Polychaeta - 4 (11.11%).

Interpretation of the data on food of P. borealis was considered only in descriptive terms. Difficulty in identification did not permit further analysis of the data. Data on feeding, however, were more reliable and not prone to the same problems.

Figure 18 presents qualitative feeding data for individual samples. Results were variable and the number of samples were insufficient to determine definite patterns of feeding between or within years. The data do suggest, however, that feeding in the autumn may be more intensive (i.e. less empty stomachs) than in the summer. Incidence of 'full' stomachs in the Hopedale Channel was

Table 11. Frequency of stomach fullness and contents for shrimp from the Hawke and Hopedale channels, 1973-78.

Sample	Stomach fullness[1] 1	2	3	4	Totals	Food item	Number of stomachs with contents[2] 1	2	3	4	5	6	7	8	Totals
Hawke Channel 12/11/73 Set 445 n = 359	71	72	214	2	359	Primary[3]			1	12	7		123		143
						Secondary			54	14	3		5		77
						Tertiary			5	2	1		1		9
						Totals	1		60	28	11		129		
Hawke Channel 10/12/74 Set 410 n = 244	45	44	155		244	Primary	1			5	21		61	1	89
						Secondary							1	1	2
						Tertiary									
						Totals	1			5	21		62	2	
Hawke Channel 16/07/75 Set 005 n = 296	15	36	241	3	296	Primary			3		1		48		52
						Secondary			15	2			1	1	19
						Tertiary			2						2
						Totals			20	2	1		49	1	
Hawke Channel 01/09/75 Set 027 n = 302	14	46	243		302	Primary			6	15	4		34		59
						Secondary			13			1	3		17
						Tertiary									
						Totals			19	15	4	1	37		
Hawke Channel 23/09/75 Set 233 n = 335	84	101	169	1	335	Primary			2	14			149		165
						Secondary			60	13	3		2	1	79
						Tertiary			1	5	3			1	10
						Totals			63	32	6		151	2	
Hawke Channel 17/08/76 n = 298	5	50	243		298	Primary			8	1			44	2	55
						Secondary			40				10		50
						Tertiary			3					9	12
						Totals			51	1			54	11	
Hawke Channel 31/08/77 Set 003 n = 349	12	109	227	1	349	Primary				121					121
						Secondary								2	2
						Tertiary									
						Totals				121				2	
Hopedale Channel 18/08/77 Set 003 n = 304	1	89	213	1	304	Primary			1	89					90
						Secondary									
						Tertiary									
						Totals			1	89					
Hopedale Channel 13/11/77 Set 475 n = 288	8	148	131	1	288	Primary	16	3	27	22	1		79	8	156
						Secondary			2	13			11		26
						Tertiary							1		1
						Totals	16	3	29	35	1		91	8	
Hopedale Channel 14/08/78 Set 015 n = 231	6	57	168		231	Primary		4	3	9			47		63
						Secondary	1		2	5	1		1		10
						Tertiary				1					1
						Totals	1	4	5	15	1		48		
Hopedale Channel 15/08/78 Set 018 n = 133		30	103		133	Primary		1	3	3			23		30
						Secondary	1		1	3	1				6
						Tertiary									
						Totals	1	1	4	6	1		23		
Hopedale Channel 28/09/78 Set 688 n = 271	18	113	136	4	271	Primary	2	1	25	5	2		94	1	131
						Secondary			3	14	1		1		19
						Tertiary									
						Totals	2	1	28	20	3		95	1	
Hopedale Channel 29/09/78 Set 692 n = 398	13	166	218	1	398	Primary	17	14	28	7			113		179
						Secondary			14	6	2		13	1	36
						Tertiary				1					1
						Totals	17	14	41	14	2		126	1	
Grand Totals	273	1060	2461	14	3808	Primary	36	23	107	304	36		815	12	1333
						Secondary	3		204	70	11	1	48	6	343
						Tertiary			11	9	4		2	10	36
						Totals	39	23	322	383	61	1	865	28	
%	7.20	27.94	64.87			Primary	2.70	1.73	8.03	22.81	2.70		61.14	0.90	100.00
						Secondary	0.87		59.48	20.41	3.21	0.29	13.99	1.75	100.00
						Tertiary			30.56	25.00	11.11		5.56	27.78	100.00

[1] Stomach fullness: 1 - Full; 2 - Some; 3 - Empty; 4 - No record.

[2] Contents: 1 - Detritus; 2 - Phytobenthos; 3 - Sand or mud; 4 - Crustacea; 5 - Polychaeta; 6- Foraminifera; 7 - Unspecified digested material; 8 - Other.

[3] Primary, Secondary, Tertiary refer to importance of items found in each stomach based on relative amounts present.

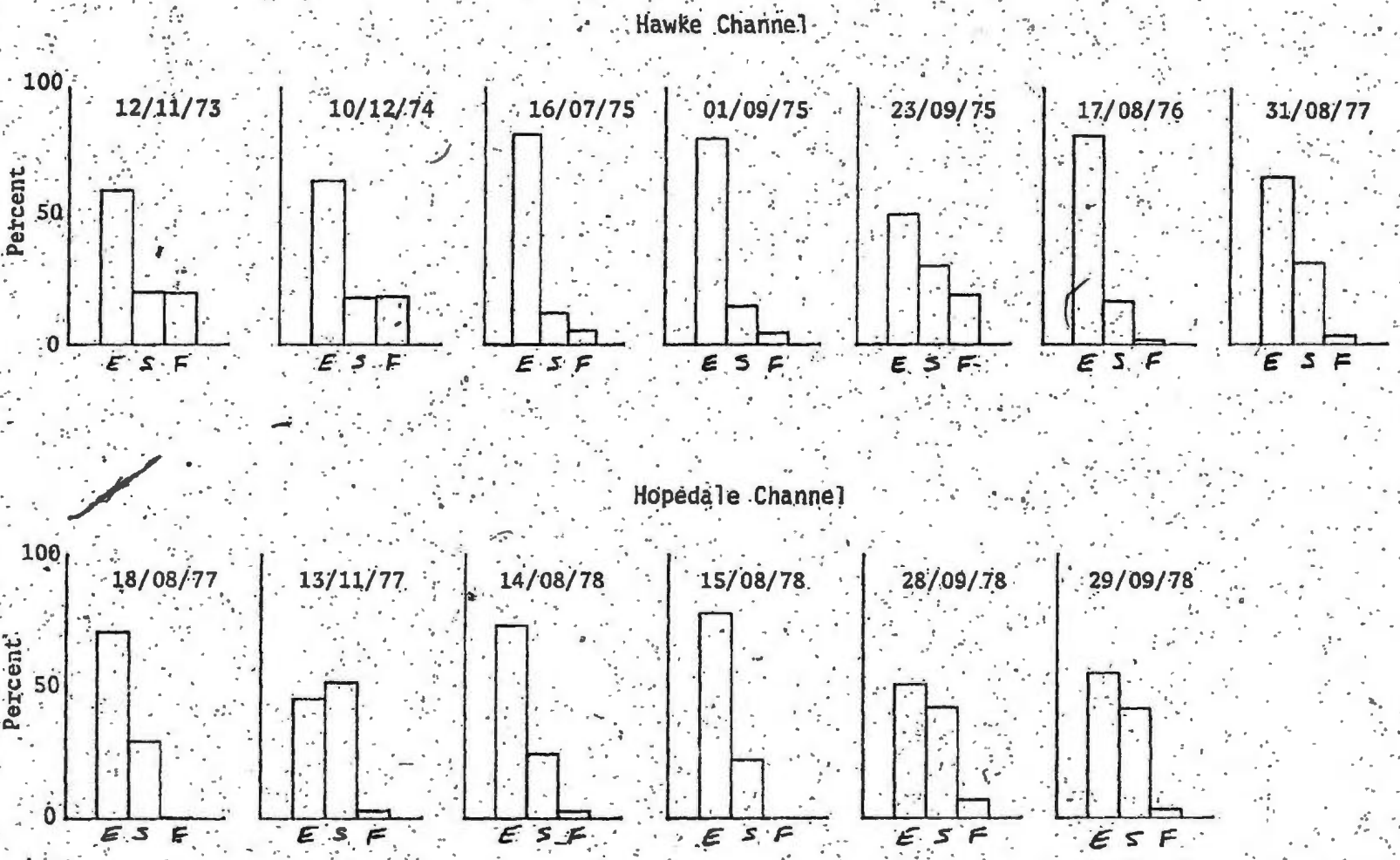


Fig.18. Shrimp feeding - Hawke and Hopedale Channels, 1973-1978.
E = empty, S = some, F = full.

lower than in Hawke Channel while those with 'some' appeared more frequently. Empty stomachs were more numerous in the Hawke Channel.

The sample from Hopedale Channel (15/08/78) was selected to determine whether or not difference in feeding occurred relative to sex and maturity of animals sampled. Animals were not feeding heavily at this time since no stomachs were recorded as 'full' (Fig. 19). Approximately 45% of males (13 of 29) contained 'some' food in the stomachs while the remaining were empty. Only 16.35% (17 of 104) females contained food. Females were divided into two groups, ovigerous and non-ovigerous. Food was found in 32.14% (9 of 28) of stomachs of ovigerous females while only 10.53% (8 of 76) of non-ovigerous females contained food.

Parasites of Shrimp Eggs

Details of the observations on each specimen are given in Appendix III. All shrimp examined macroscopically possessed opaque eggs which were interpreted to be non-viable (Fig. 20). The proportions of non-viable eggs ranged from 0.39 to 24.29% of all eggs in the clutch.[5] From a total of 67,624 eggs counted, 3903 (5.77%) were classified as non-viable (Table 12). Each shrimp averaged 1439 eggs (± 332) of which 1356 (± 316) were viable and 83 (± 78) were non-viable.

Microscopic examination of subsamples of these non-viable eggs revealed that varying proportions were partially or totally filled with apparent parasitic organisms (Fig. 21a, b). These were unicellular, spherical or ovoid and approximately 6.3 µm (5.6-7.2 µm; n = 20) in diameter. The single nucleus was around 2.4 µm (1.6-3.2 µm; n = 20) in diameter.

[5]These figures represent the percent of all eggs which were totally or partially opaque and noticeably swollen.

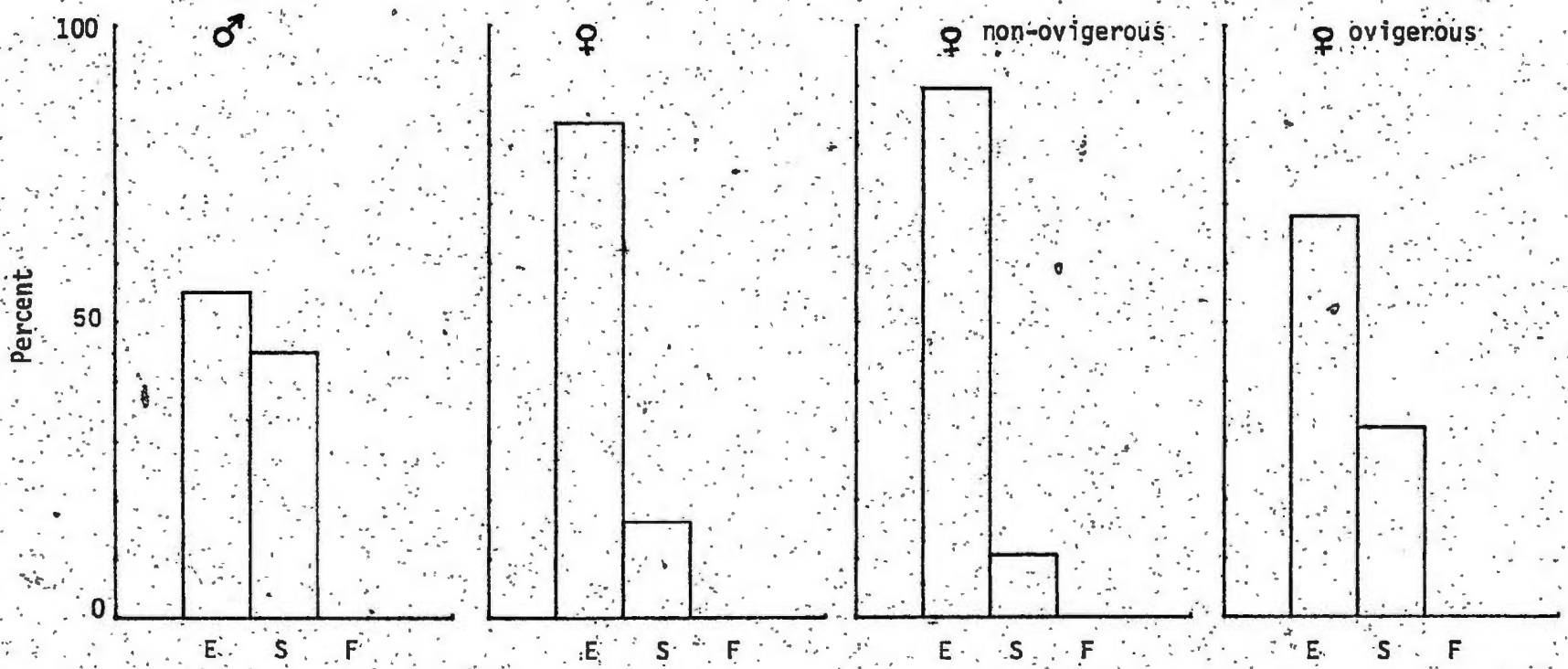
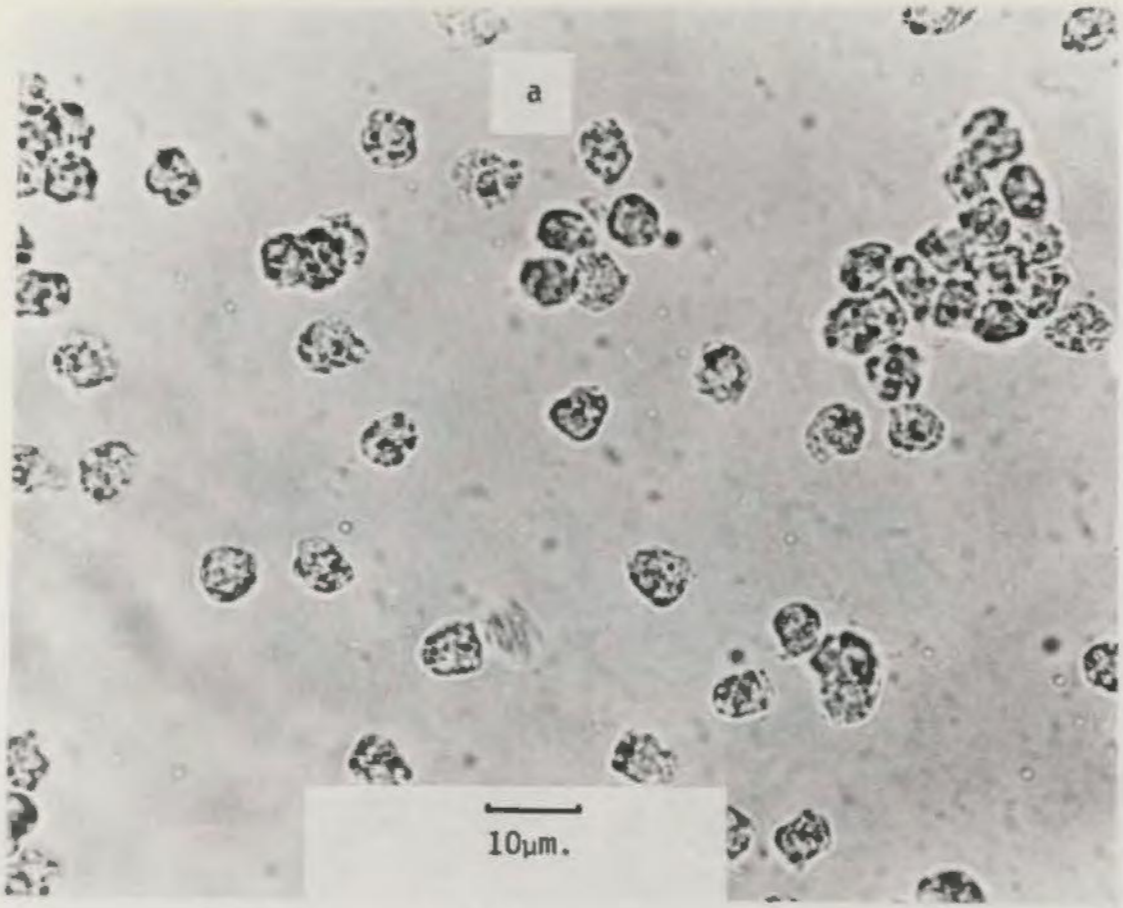


Fig.19. Shrimp feeding by sex and maturity stages - Hopedale Channel, 15/08/78.
E = empty, S = some, F = full.

Fig.20. Occurrence of opaque, non-viable eggs among healthy eggs of a female shrimp (Pandalus borealis).



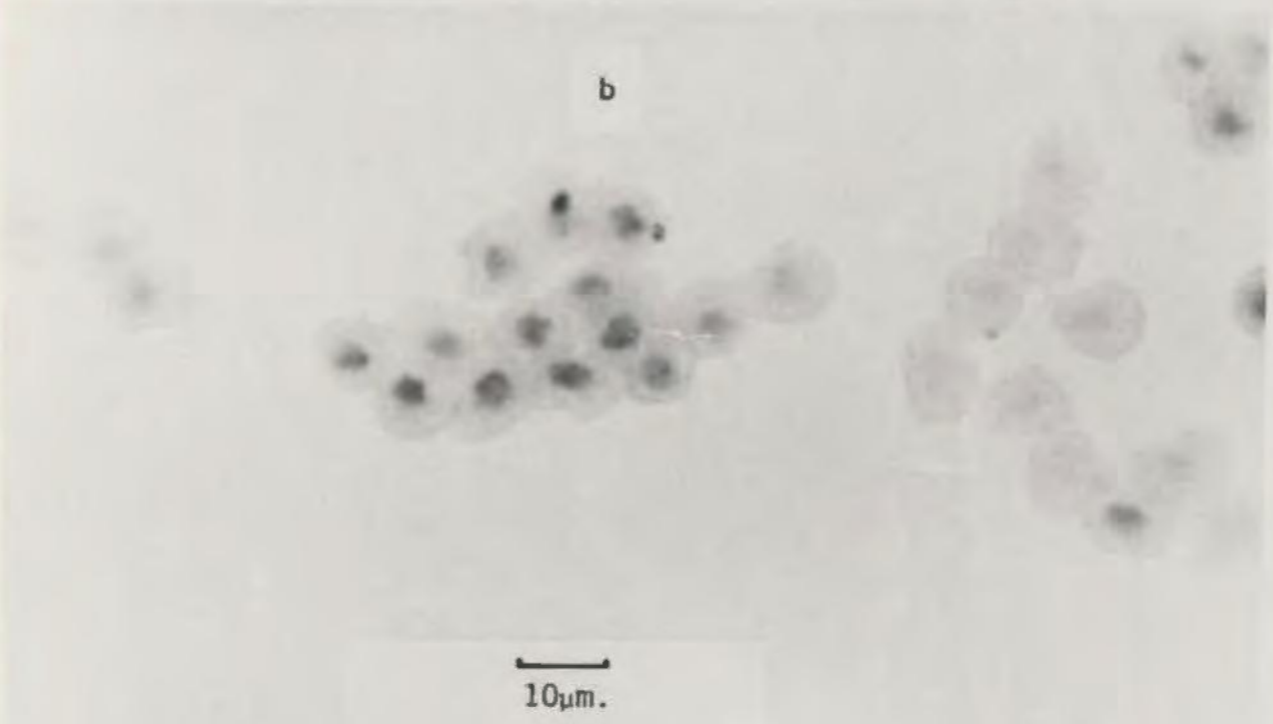


Fig.21. Parasites observed in smears of shrimp eggs; a) unstained, b) stained with Giemsa colophonium.

Table 12. Proportions of viable and non-viable eggs in shrimp (Pandalus borealis) from the Cartwright Channel (1979) and rate of infection with an apparent parasitic dinoflagellate.[1]

	Total eggs	Viable eggs		Non-viable eggs				
		No.	%	No.	%	No. examined	No. infected	No. infected
	67,624	63,721	94.32	3,975	5.77[3]	540	122	22.59
Mean[2]	1438.81	1355.77		82.81				
Standard deviation	332.11	315.11		77.58				

[1]Data given in Appendix III.
[2]n = 47 for 'Total' and 'Viable' entries.
n = 48 for 'Nonviable' entries.
[3]Calculated: 3975 ÷ 72 ÷ 67,624 x 100 (see Appendix III).

Prevalence of parasitism varied from 0 to 70%. A total of 122 (22.59%) of the 540 non-viable eggs examined contained these parasites. There was no apparent relationship between the size of the female and either percent non-viable or percent non-viable-infected eggs (Fig. 22a, b)

Included in a 'doubtful' category (not considered above) were eggs from 16 shrimp which contained smaller cells, the details of which were difficult to observe (Fig. 23). These cells were approximately 1 µm or less in size and, at times, completely filled the egg. Because of the extremely small size and low numbers, no prevalences were calculated.

Muscle Necrosis

Shrimp with normal and abnormal muscle are shown in Fig. 24. The 'diseased' animals were easily separated from 'healthy' ones, macroscopically. The opaque appearance of the muscle was extensive and occurred not only in the abdominal muscle but in smaller muscles of the cephalothorax, pleopods and pereiopods as well. Prevalance of the condition was very low. In July, 1981, results of a research survey showed prevalence in all areas surveyed of less than 0.10% (Table 13).

Examination of thin sections of shrimp muscle (Fig. 25a, b) showed differences between normal and diseased tissue. There appeared to be extensive muscle necrosis and some evidence of pycnosis (accumulation of dead and dying nuclei of muscle cells).

The tissue was infected with two 'types' of ovoid spores (Fig. 26a, b). Seven of the nine shrimp contained small spores which were tear-drop shaped. These were 2.3 X 1.4 µm (1.6-2.8 X 1.0-1.6 µm;

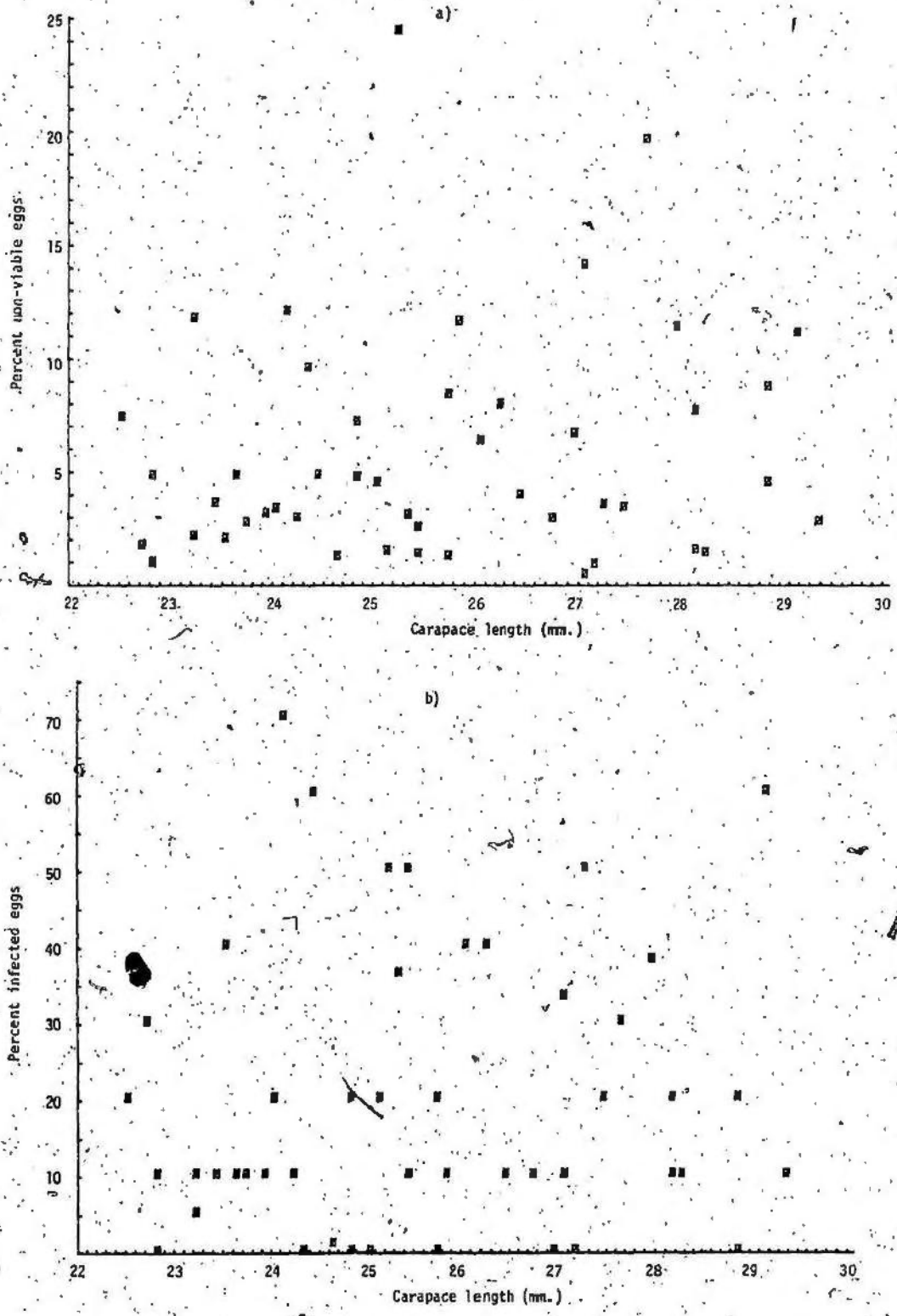


Fig.22. Relationships between proportions of non-viable and infected eggs and carapace length - Cartwright Channel, 1979.

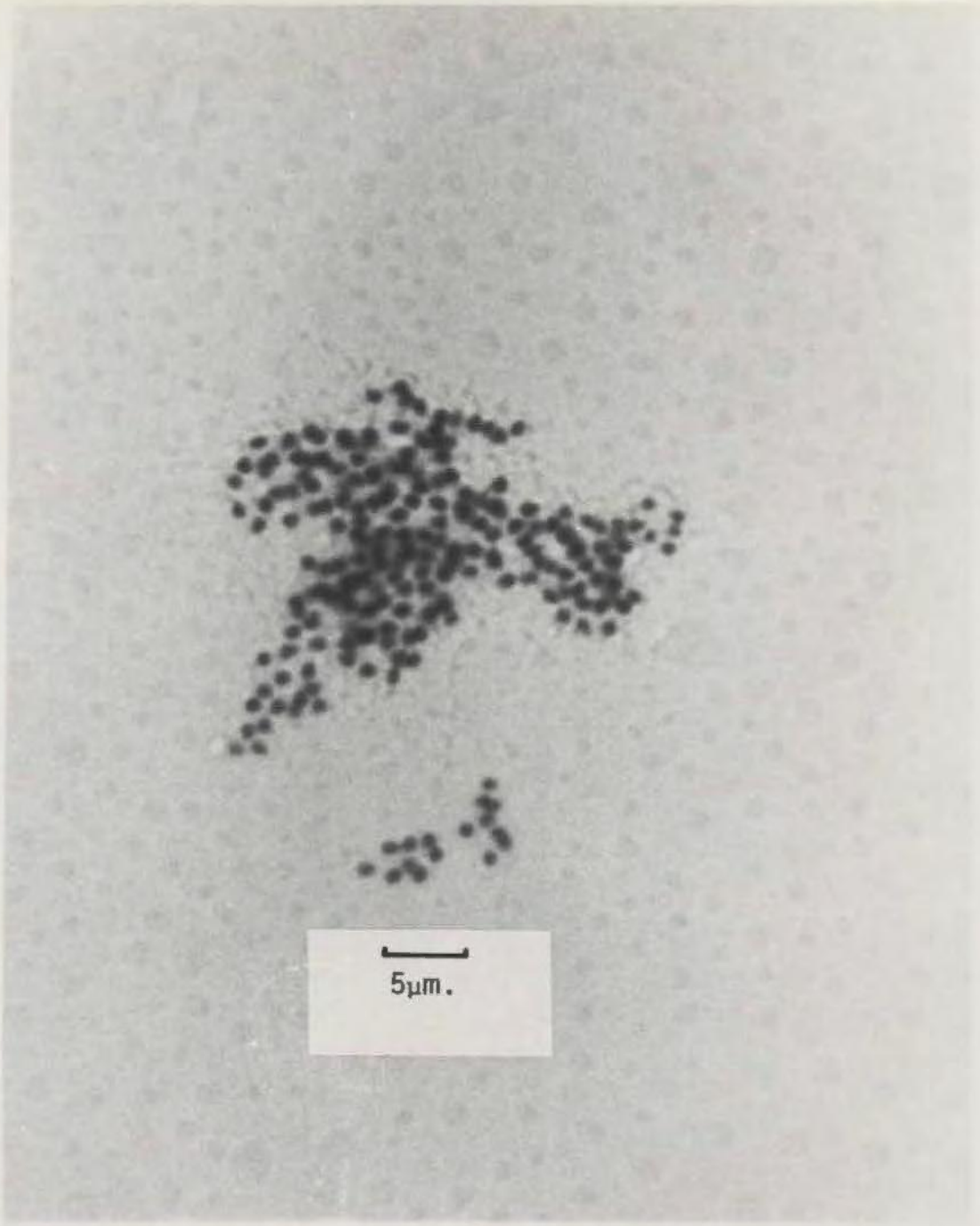
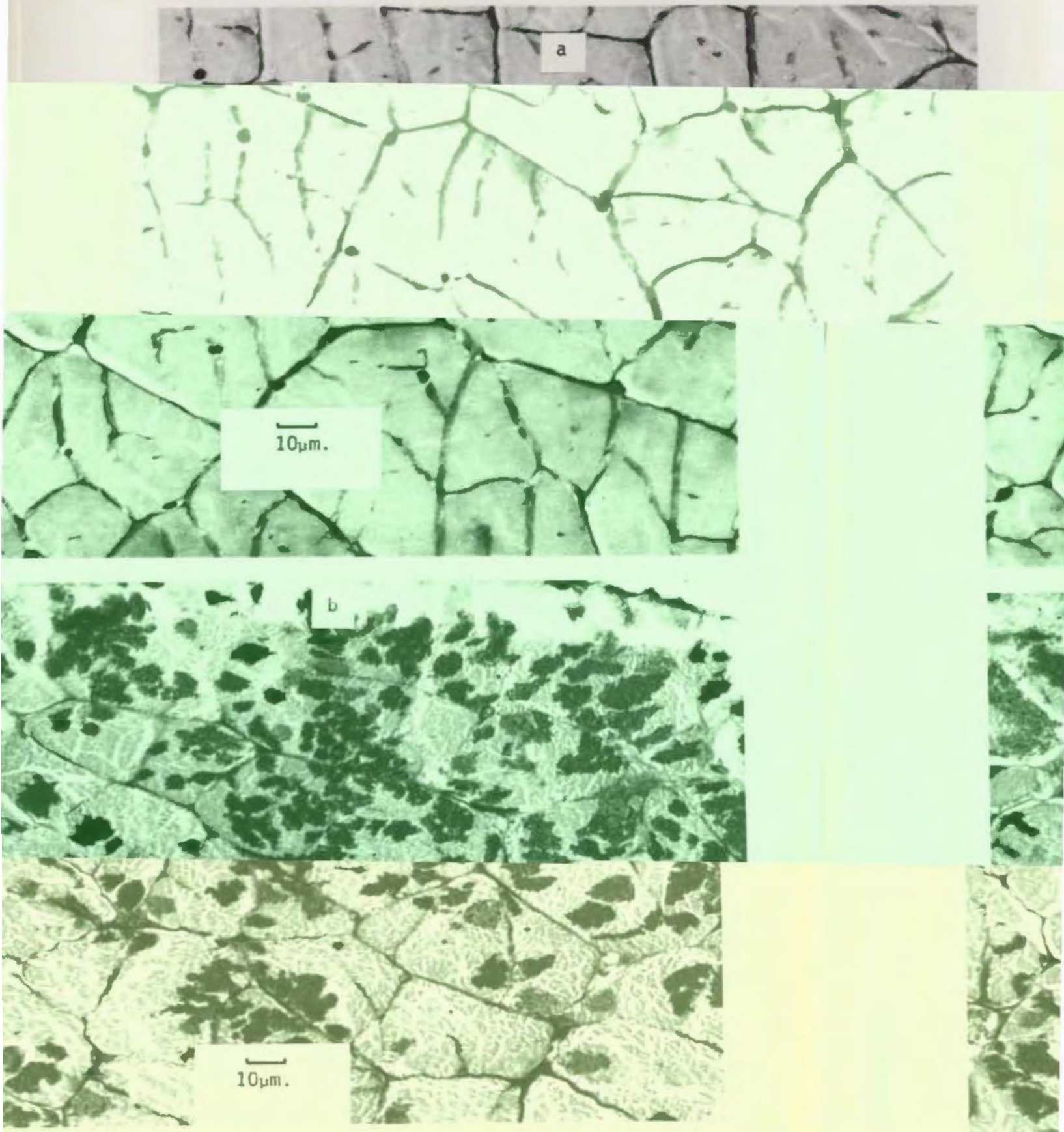


Fig.23. Small spores observed in shrimp eggs (not included in infection rates) stained with Giemsa colophonium.

Fig.24. Normal a) and abnormal b) striated muscle of the shrimp Pandalus borealis.

Table 13. Prevalence of opaque musculature in Pandalus borealis from the Northwest Atlantic.

	No. measured	No. opaque	% opaque
Hopedale Channel	22437	3	0.01
Cartwright Channel	15170	9	0.06
Hawke Channel	5942	1	0.02
Division 3K	4604	0	0.00
TOTAL	48153	13	0.03



Cross-sections of normal a) and diseased b) abdominal muscle stained with hematoxylin and eosin.

Fig.2

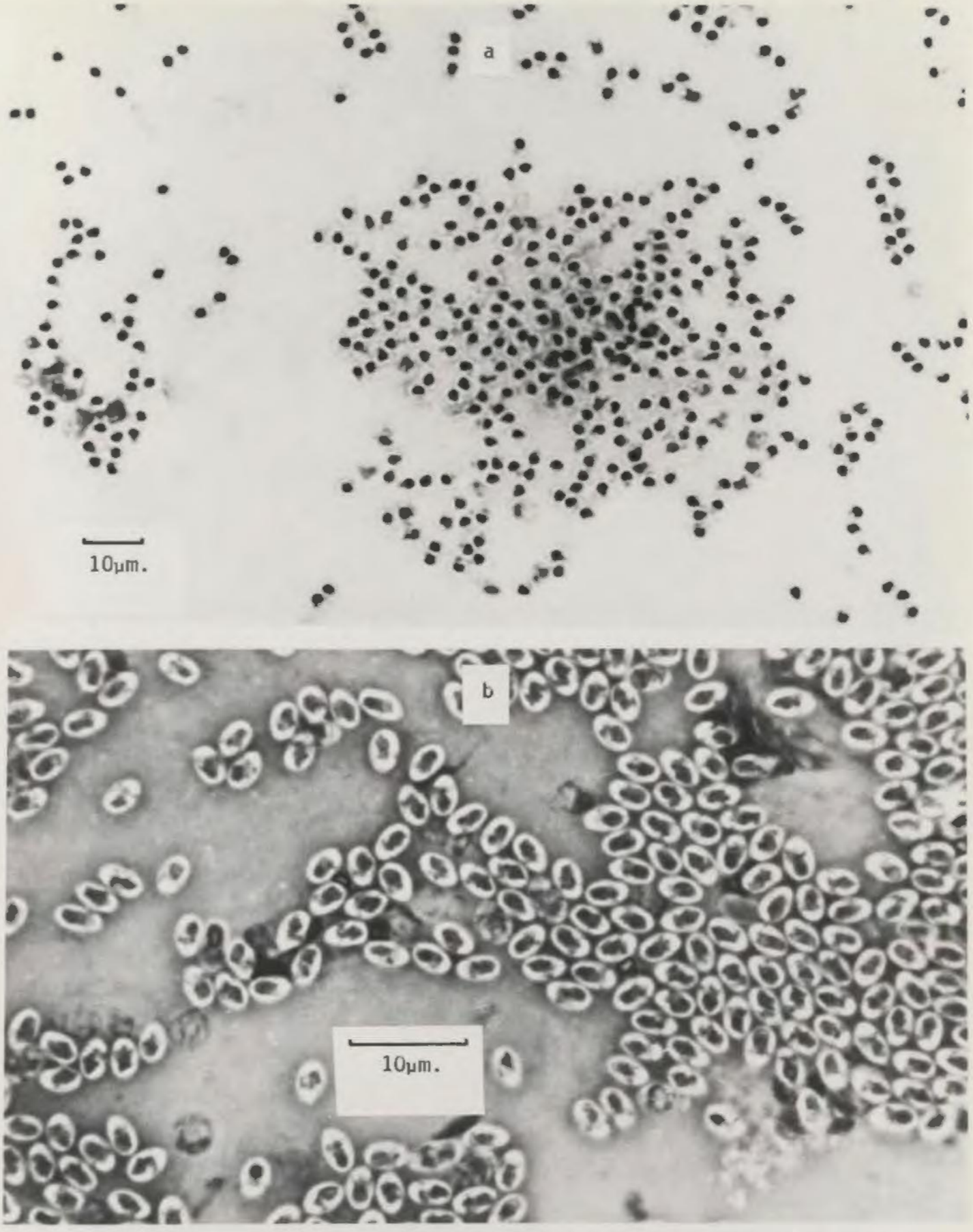


Fig.26. Small spores a) and large spores (phase contrast) b) from shrimp abdominal muscle stained with Giemsa colophonium.

n = 20). The other two shrimp contained larger spores with rounded ends which measured 3.9 X 2.4 μm (3.6-4.4 X 2.4-2.8 μm; n = 20). These observations were made from smears of fixed material. Electron micrographs of the small spores are shown in Fig. 27.

Seen in cross-section of muscle tissue (Fig. 25b), spores occurred in clumps or colonies which were most numerous near the periphery of the muscle and less dense toward the central portion.

Data were not sufficient to determine if the condition was related to size or age. It is important to note, however, that the infected animals ranged in size from an 18.9 mm (carapace length) male to a 26.7 mm female.

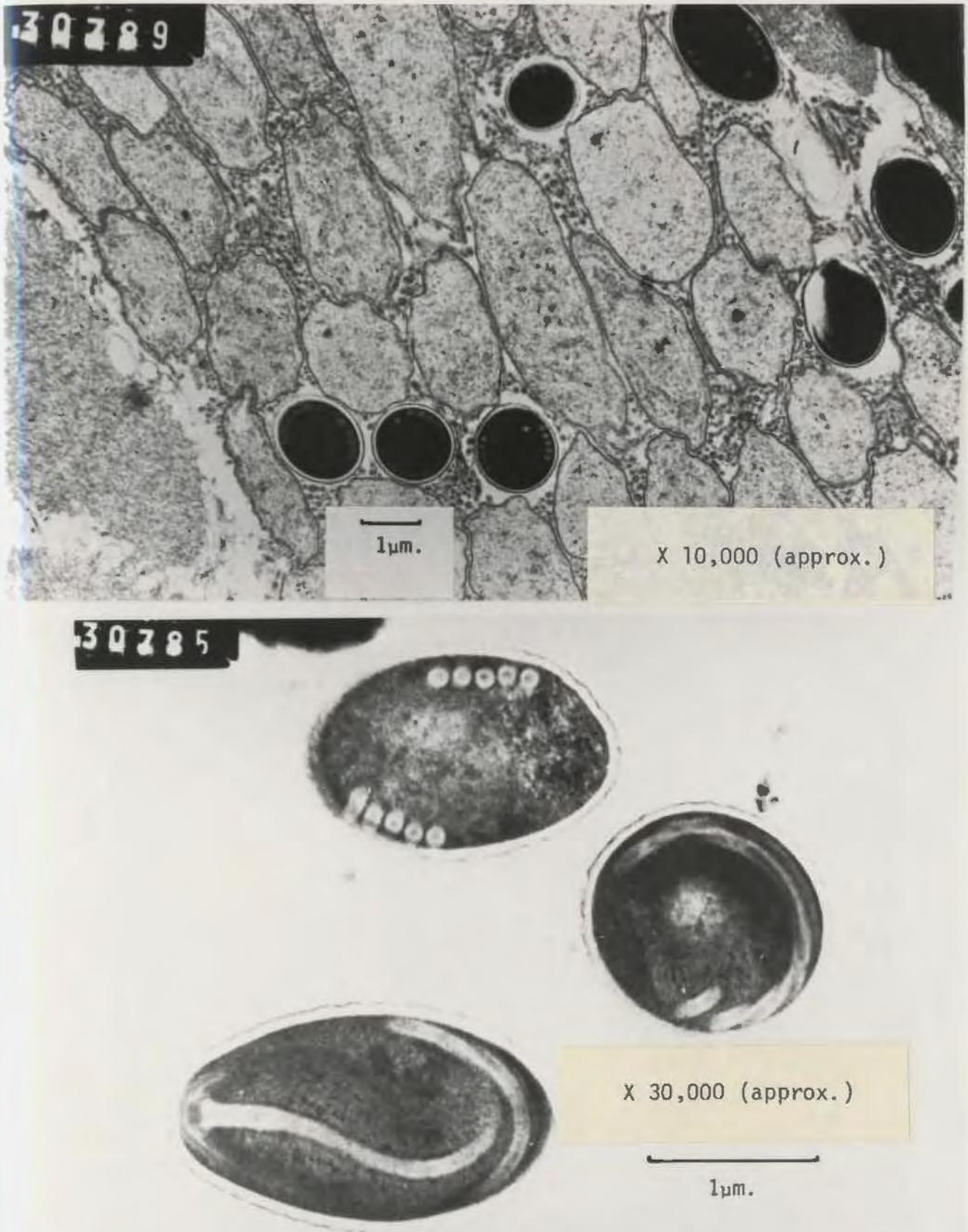


Fig.27. Electron micrographs of microsporidian spores found in shrimp abdominal muscle.

DISCUSSION AND CONCLUSIONS

Distribution

A. Horizontal Distribution

Shrimp off coastal Labrador were concentrated in depressions (or channels) in the Labrador Shelf. Hydrographic data revealed that these areas contained relatively warm water (2-4°C) overlain by colder (-1 to 2°C) water (Parsons et al. 1980). The warmer water and muddy bottom present in these channels provided conditions favourable for shrimp (see INTRODUCTION). The Hopedale and Cartwright Channels were not sampled on the western slopes because of irregular topography but it has been shown that shrimp occur in these areas (sampling by shrimp pots) and the substrate is mainly mud (Parsons et al. 1980).

The data from the present study indicated that shrimp in all three areas were most abundant at depths greater than 300 m. Hawke Channel differed from the two more northerly areas since shrimp were never found in large quantities in the deepest part of the channel. However, large catches were common in some years from the deepest water in the northern Hopedale and Cartwright Channels. Hopedale and Hawke Channels generally showed specific areas of concentration within channels with lower abundance elsewhere. This was not evident in the Cartwright Channel.

Observations between years showed variability in depth distribution for all three areas. This fact, coupled with evidence of vertical migration and/or diel variability (see INTRODUCTION and Diel Variability

sections), suggest that shrimp are capable of extensive movement ultimately limited by cold water barriers and/or suitable substrate. Therefore, it seems reasonable to assume that shrimp also have the ability to react to fishing pressure which may manifest itself in dispersal of heavy concentrations or displacement of the concentrations to different areas.

Abundance in July was generally high but it has been suggested (Parsons and Sandeman 1981) that during the year availability to sampling gear may change. The shrimp fishery in Labrador usually starts in the June-July period and is characterized by high catch rates. These decrease as the season progresses and the decreases can be attributed at least partially to fishing pressure. However, Parsons and Sandeman (1981) also stated that even in areas where fishing pressure is low a decline in abundance could still be observed which would suggest some seasonality in patterns of abundance. This reasoning is supported by the fact that catch rates generally improve later in the year (Nov.-Dec.). Seasonal distribution patterns have also been observed in the Davis Strait shrimp fishery (Atkinson et al. 1981).

A number of factors can influence changes in distribution patterns between years. Data from the Hopedale Channel showed an overall decline in catch rates in the 1981 survey compared to levels obtained in the previous two years. Abundance was interpreted to be similar between 1979 and 1980 considering indices of biomass and commercial catch per unit effort (Parsons et al. 1981a). The fishery in Hopedale Channel, however, started earlier in 1981 than in other years and sustained fishing pressure on the stock might

have resulted in lower catches during the research survey. On the other hand, fishing effort was confined to the northern part of the channel. Nevertheless, there seems to be an overall decrease of catch rates in 1981. A large increase in the abundance of Greenland halibut (Reinhardtius hippoglossoides), a primary predator of shrimp, was observed in the Labrador 'shrimp' channels in 1980 (Bowering and Parsons 1981) and might have had an effect on distribution and/or abundance. It is more likely, however, that the pattern of seasonal availability was different compared to the previous two years, affecting catchability of the research trawl and resulting in lower catch rates.

In the Cartwright Channel stability in abundance was interpreted from catch per unit effort indices and biomass estimates (Parsons et al. 1981a). Highest catches in the 1981 research survey exceeded those of the previous two years but shrimp concentration appeared to be greater over a smaller area in somewhat shallower water. The shrimp resource in this area was not heavily exploited in 1980 and 1981 since catch rates were higher in the Hopedale Channel and Davis Strait. The increase in abundance of Greenland halibut in 1980 also occurred in this area and presumably increased predation might have limited any resurgence of the stock resulting from a reduction in fishing mortality. Therefore, although peak catches in 1981 were almost twice those obtained in 1979, it was interpreted that stock abundance might not have changed greatly over this period.

Both patterns of distribution and abundance appeared to have changed from 1979 to 1981 in the Hawke Channel. In 1979 and 1980, best catches were obtained on the northern side of the channel

whereas in 1981 the highest catches were obtained in the southern areas. The data presented also showed that catch levels were lower in 1981 than in 1980 and 1979 respectively. Shrimp research off Labrador began in this area during the 1970s and commercial catch rates as high as 600 kg/hr have been reported (Parsons et al. 1979). The best research catch obtained in the 1979 survey was 256 kg compared to 83 in 1980 and 43 in 1981. Although these figures were not considered to be abundance indices they do suggest an overall decline in the shrimp resource in this area. Since virtually no commercial fishing has occurred in this channel the population decline appeared to be a natural occurrence. Although temperatures were slightly higher in 1980 than in 1979 or 1981, there were no indications that temperature in the area was undergoing any cooling trend during this period.

B. Size Distribution

The characteristic of increasing size with depth has been shown for numerous shrimp stocks in the northwest Atlantic (Parsons 1979, Fréchette and Dupouy 1979, Parsons et al. 1979, 1980, 1981a). Higher proportions of small animals were also noted in the shallower water for stocks of P. montagui in Ungava Bay and Hudson Strait (Parsons et al. 1981b).

Larger female shrimp in the Gulf of Maine and Gulf of St. Lawrence characteristically are known to migrate to shallower water during the ovigerous period (Apollonio and Dunton 1969, Parsons and Sandeman 1981) and may be limited in this migration by temperature barriers. The surveys reported here occurred in July in each year,

when females were not normally carrying eggs. Length frequencies for the Hopedale and Cartwright Channels for November, 1977, presented by Parsons et al. (1979) showed high proportions of ovigerous females in the shallower part of the depth range and this obscured the trend toward increasing size with depth evident in the figures presented above. Length frequencies from a survey in September-October, 1978 (Parsons et al. 1979) showed the increase in size with increasing depth but densities at the time were very low. Large numbers of ovigerous females were present during this period as well. No data were available from winter and spring months (January-June) since ice and/or inclement weather precluded commercial or research fishing in these areas during this period.

Shrimp in the Labrador Channels showed increasing size with depth at least for the July to October period. Some evidence in the literature cited previously indicated that in these areas the pattern may be altered around November when females are ovigerous. This movement may be similar to the previously mentioned 'migrations' by ovigerous females to shallower water observed in the Gulf of St. Lawrence and Gulf of Maine.

A sampling design stratified by depth in areas of shrimp distribution has often been used in an attempt to improve the accuracy of abundance estimation by reducing variance associated with mean catch rates. Although the desired results have not always been obtained (Parsons and Sandeman 1981) it seems that some stratification is necessary to monitor size distribution and changes which may occur on a seasonal basis.

Northern shrimp fisheries have traditionally been directed at the larger animals (eg. Horsted 1978b). Size preference, in the case of a protandric hermaphrodite, means higher fishing mortality on females. Provided the species can maintain an adequate spawning stock (see Sex and Maturity section) recruiting year-classes should not be greatly affected by fishing pressure. In addition, vessels generally avoid shallower water (<300 m) where smaller shrimp are abundant (Fig. 6 and Parsons et al. 1979-81a).

C. Diel Variability

Diel variability has been associated with vertical migration (see INTRODUCTION) which, in turn, might be connected with nocturnal pelagic feeding (Barr 1970). Jones and Parsons (1978) showed diel changes in the proportion of ovigerous (larger) animals occurring in the catches in the Davis Strait. The data were also used to establish midnight and noon plateau periods from which conversion factors were derived to correct for optimum catch. Barr (1970) showed that a greater proportion of larger shrimp in Kachemak Bay, Alaska, occurred in bottom trawl catches at night and that shrimp pots suspended vertically in the water column caught a higher proportion of small animals than those set on bottom.

Data from the Hopedale Channel showed marked changes in catch rates over the 24-hour cycle. The pattern of diel variability also differed between 1980 and 1981. Largest catches from depths around 550 m occurred later in the afternoon in 1980 (1500-1800 hours) compared to late morning in 1981 (0800-1000 hours) from depths around 350 m. The pattern of change in average size over a 24-hour cycle did not differ greatly between the two years. Smallest weighted average

size occurred just before noon in both years and the largest were present just before midnight. This indicated that vertical migration was more extensive for the smaller than larger animals. These changes in size composition were characteristic of the vertical movement described by Barr (1970) and could be considered a diel rhythm since the period was approximately 12 hours. If changes in catch rates in a given area over a 24-hour period were due only to vertical migration, then there should be some relationship between catch rate and size of shrimp, with larger sizes being associated with smaller catches and vice versa. This would also imply that shrimp of all sizes should be most available to bottom trawls around noon. Such a relationship between catch and size of shrimp was not evident from the Hopedale Channel in 1980 and 1981. Parsons (1979) reported that catches over a 24-hour period in the Davis Strait were not closely related to changes in the proportion of ovigerous (larger) animals although both exhibited a diel rhythm. It also should be noted that shrimp were not ovigerous at the time of these Labrador surveys (summer and early fall); therefore, larger animals (females) were not restricted in mobility by the presence of eggs on the pleopods.

Although a diel trend can be interpreted from the Labrador data in terms of highest and lowest catches, it cannot be associated entirely with the trend in size which may be linked with vertical migration. Sandeman (pers. comm.) suggested that the Davis Strait data (Parsons 1979) possibly reflected the effects of tidal currents. A further interpretation of the data was presented by Parsons and Sandeman (1981) which showed that catches for that day could be

closely modelled by a sine curve with a period of six hours, (approaching the half period of the dominant semi-diel tide of the area) superimposed on a linear saw-tooth curve (representing the normal diel effect). Since the tidal model is based on a lunar day of 24.8 hours and the vertical migration is based on a solar day of 24 hours (Palmer 1976), the two rhythms probably interact in a complex manner that affects the peaks in catch rate data. Irregularities were present in the catch rate data from the present study which might have reflected the semi-diel pattern discussed above (especially in 1980).

Other factors contribute to the problem of understanding shrimp distribution and availability. Vertical migration should also be variable with depth since there is a definite size-depth relationship (see previous section). Therefore, vertical migration should be more pronounced in shallower water and less in deep water. If this does occur, it would not appear to account for the differences observed above (between 1980 and 1981) since maximum concentrations (including larger shrimp) were present in shallower water in 1981 and only amplitude in patterns of catch rate should be affected, not period. If vertical migration is related to changes in light intensity, then patterns can also be expected to change with season. This has been interpreted from commercial data collected off West Greenland (Carlsson et al. 1978, Smidt 1978). The extent of vertical migration is likely limited in these areas by layers of very cold water (<1°C). In July, these cold water 'barriers' occur at depths in excess of 200 m (see Tables 1 and 3); but stratification of the complete water column is not constant year-round. Age and size composition of the population will also change between years especially when strong year-classes appear.

Therefore, the degree of vertical migration can be expected to change also between years.

The effects of environmental factors such as tidal currents might influence behaviour of the shrimp, the sampling gear, or both. The vertical migration model based on changes in average size predicted optimum availability around noon, whereas a tidal model would predict variability between days depending on such things as speed and direction of the currents. Thus, it would appear that vertical migration would not entirely explain the variability inherent in the results presented above but that such variability is likely associated with a number of complex environmental factors which affect shrimp distribution and availability to bottom sampling gear and even with the efficiency of the gear, itself.

Sex and Maturity:

Shrimp samples taken from two Labrador channels in July, 1980, showed similarity in sizes at different sexual stages. Males attained maximum lengths of approximately 23 mm, transitionals ranged from 20-26 mm and females usually occurred at sizes greater than 21 mm. The reduction in the proportion of males occurred over a slightly wider range of sizes in the Cartwright Channel samples than in those from the Hopedale Channel.

Incidence of transitional animals was high relative to first-year females. Combining both groups resulted in a single mode in the length frequencies indicating that these animals possibly belonged to the same year-class. Ripening ovaries indicated that both stages would spawn in that year. A smaller peak of mainly transitional animals was evident in the Cartwright Channel data. This group might have been a part of the previous cohort of males and represented

the faster growing animals in that year-class. Numbers, however, were low and might have represented noise in a unimodal distribution. Frequency of sampling within a season was not great enough to indicate duration of the transitional phase. The single prominent peak of multiple spawners was interpreted as second-year females. Modes beyond the latter were not clear but their presence suggested multiple spawning occurred beyond the second year. Occurrence of females which had spawned previously with unripening ovaries showed that a certain proportion might spawn intermittently rather than annually. This was observed only in the detailed sample from the Hopedale Channel.

Ogives constructed from the sex and maturity data indicated that sex change could have occurred at similar sizes in the two channels in 1980. However, length frequencies from a 1978 (September) survey suggested sex change at smaller sizes in the Cartwright Channel than in the Hopedale and Hawke Channels. These 1978 data also showed that a small proportion of animals less than 20 mm in the Hawke Channel were carrying eggs (unlike the other two areas) and that the proportion of non-ovigerous females (apparent in all channels) was highest in the Cartwright Channel.

Effects of fishing might not have been apparent in 1978 since the commercial fishery commenced in 1977. However, by 1980, some reaction to increased mortality could have been expected. Comparison of the ogives constructed from samples within channels and between years suggested some decrease in size at sex reversal, especially for the samples from the Hopedale Channel. This interpretation assumes that any growth which might have occurred between sampling seasons (July vs. September) only partially explains these differences.

The slight differences in the ogives between years for the Cartwright Channel also must be interpreted in relation to the nature of the data. The 1978 data shows proportions of non-ovigerous animals rather than an accurate breakdown by sex. The curves (Fig. 12 and 13) parallel the X-axis at sizes where all animals are male (left) or female (right). However, some adjustment must be made for the small proportion of non-ovigerous females. If this proportion is reasonably consistent over the entire size range of females and the adjustment is made to reflect sex rather than maturity, the slope of the descending part of the curve increases but the initial declining proportions remain unchanged. The slight differences which were evident at the smallest sizes within the sex change range indicated the possibility of some reduction in size at sex reversal between years for this area as well, but may represent only random variation between samples.

Under virgin conditions the size at sex change appeared smaller in the Cartwright Channel than in the other two areas. This difference becomes even more pronounced when the adjustment for non-ovigerous females (described above) is applied. After exploitation, this size apparently decreased at least in the Hopedale Channel. The magnitude of the decrease, might have resulted in coincidental similarity of the data between the two areas in 1980.

These results were consistent with those for P. borealis in other areas in that under stable environmental conditions sex change occurred following attainment of some size threshold (eg. Rasmussen 1969, Hoffman 1972). Maturity data showed that shrimp off Labrador do not produce early maturing females (i.e. no male phase) described by Butler (1970). Squires (1970) stated that this

condition is usually related to warmer water populations but extreme cold retards growth and maturation to the extent that in some areas males may never change sex. The inability of all females to spawn annually, as observed in the data from Labrador, probably reflects the effects of cold water in these areas. Differences observed in size at transition between samples from each channel could represent stock differences possibly due to different environmental conditions in each area (eg. temperatures, density) which may affect physiological processes in different ways. Slightly colder waters in the Cartwright Channel (see Distribution) for example, might have been responsible for smaller sizes at sex change observed in the samples from that area.

Differences within channels and between years also could be attributed to changes in environment but may reflect the effects of commercial fishing as indicated previously. A reduction in size such as that observed between 1978 and 1980 might be due to a number of factors including fishing pressure directed at the larger animals, a common observation in exploited stocks. Charnov (1981), however, attributed similar changes in P. borealis at Skagerrak (between Denmark and Norway) to the buildup of the shrimp fishery, rather than the size threshold theory. The shrimp fishery is selective of larger animals (females) and should result in an alteration of the male/female ratio over a relatively short time. According to Charnov's theory, if there are too many males in the population, selection will favour mutants which spend more time as females. Increased mortality on females through fishing should produce such conditions resulting in faster-maturing females (i.e. at an earlier age). It also seems possible that such sex ratio

optimization could occur as a result of natural phenomena (such as size-selective predation) as well as fishing.

However, the data in the present study merely reflect the possibility of changes in size at sex reversal. There is no evidence to suggest that the age at sex reversal has decreased. In this light, any such changes may be interpreted only to reflect reponses to fishing mortality directed at larger animals, changes in growth rates between year-classes and/or differences due to growth between sampling periods (i.e. July vs. September).

Weight-Length Relationships

The relationships between weight and length for samples from the three Labrador Channels were similar for males (animals less than 21 mm carapace length). Females (21 mm and greater) showed differences which were statistically significant. The greatest weight at a given length occurred in shrimp from the Hopedale Channel sample, followed by samples from the Hawke and Cartwright Channels, respectively. A comparison with data from other areas showed that the curves for the Labrador areas fell within a relatively narrow range bounded by the extremes which were represented by the relationships for the Gulf of Maine (Haynes and Wigley 1969) and the Esquiman Channel in the Gulf of St. Lawrence (present study).

Some of the observed differences could be due in part to changes in weight between fresh and preserved samples. To determine the effects of preservation in 10% formalin, a sample from the Gulf of St. Lawrence was measured before and after preservation (Fig. 15a). The log-log relationships were compared by analysis of covariance which showed that slopes ($P = 0.024$) were different. Weight at length was greater for preserved animals by approximately

0.25 to 1.0 g over the range of sizes. No appreciable shrinkage was evident since the mean length of the sample remained essentially the same (20.5 mm). These results were in contrast to the expected situation and observations made by Apollonio and Dunton (1969) who demonstrated that live weights were about 0.3 to 0.4 g heavier than preserved (5% formalin) weights.

The interpretation of the statistical analyses must, however, be made with caution. Part of the differences evident among the female group could have been influenced by the few samples available for the larger sizes. Even with correlation coefficients close to 1, the possibility exists that samples from within the same area could have differed significantly. However, data were not available to demonstrate this point.

The above analyses have been made using predictive regression in order to facilitate the analysis of covariance. Ricker (1973, 1975) suggested that a functional regression should be used for the weight-length relationships to give an unbiased estimate of the exponent, since errors of measurement will occur for both length and weight. The slope in the log-log relationship is estimated

by $b = \frac{\Sigma XY}{\Sigma X^2}$ in predictive regression,

and by $v = \left(\frac{\Sigma Y^2}{\Sigma X^2}\right)^{\frac{1}{2}}$ in geometric mean

functional regression. Ricker further shows that $v = b/r$ where r is the linear correlation coefficient. Since values of r from the Labrador data are very close to unity, then $v = b$ and the degree of bias by using the predictive regression is minimal.

Pienaar and Thompson (1969) demonstrated that the use of log-log transformation on weight/length data can also lead to errors in the parameters obtained. By a plot of residuals against Y they showed some indication that the variance of log weight (W_i) is not constant as assumed in the linear regression model. Transformation of variables apparently overcompensates for the anticipated increase in variance of W_i for larger fish. They conclude that 'the observations on smaller fish receive a disproportionately high weight and the estimates, although still unbiassed, will not be the best'.

Although these problems were not directly addressed, it is felt that the extremely good fit of the data did not require any weighting procedures or alternative models, i.e. errors are negligible.

Generally, weight-length relationships for shrimp in areas off Labrador showed some similarity to those reported for the same species in other parts of the world. Variation in the Labrador data is low but a statistically significant difference exists in some of the comparisons between the areas. Therefore, for general purposes, pooling of data from all these areas could be considered but the individual equations should be recognized when employing models which are sensitive to such input (eg. yield-per-recruit calculations). A useful exercise would be to compare samples from within the same channel. It is also advisable to compare data for non-ovigerous animals since those carrying eggs will show quite different length/weight relationships. Any comparison of ovigerous animals would have to consider differences in clutch size, egg mortality, and egg loss (see Fecundity section).

Fecundity

Some differences in average number of eggs for shrimp in the Labrador Channels were interpreted from the foregoing analyses. It was also apparent that fecundity levels possibly differed over the ovigerous period. This might have been due to incidental loss of eggs, incomplete fertilization (Elliot 1970), and/or disease. Seasonal data for Hopedale and Hawke Channels, however, were inconsistent with this hypothesis. Possibly the relationships presented differed because of small sample size and incomplete sampling at the extremities of the length range.

If egg loss does occur over the ovigerous period (Ito 1976, Stickney and Perkins 1979, Stickney 1981) and if the rate of loss is similar over the entire size range then it might be expected that relationships would be similar in slope but different in adjusted means. The lack of consistency evident in the above samples indicated that low sample size may be the main reason for the observed differences.

The lack of a demonstrable difference in fecundity between years permitted the pooling of data and increased the sample size. It also might be indicative of stable bottom temperatures in these areas since it has been suggested that temperature and fecundity are related (Anonymous 1979).

After demonstrating differences in fecundity between seasons in the same year and accounting for these differences in the analyses, conclusions similar to those of the initial run were obtained. Values of r were improved consequently for the Cartwright and Hawke Channels but decreased for the Hopedale Channel. Since the

seasonal comparisons indicated differences which were not explained completely by the "egg loss hypothesis", the low sample size is the more likely explanation.

Fecundity of shrimp in the Labrador Channels ranged from approximately 800-2700, 700-2700, and 800-2500 eggs per clutch for Hopedale, Cartwright, and Hawke Channels, respectively. The higher values of the former two areas were representative of females up to 30 mm carapace length whereas in the latter area no animals larger than 28 mm were sampled.

Since total number of eggs increased with the size of the female, comparisons with other areas must be interpreted carefully. Temperatures differ between areas and affect growth rates (Butler 1971). Therefore, in colder regions a female at a given age will likely be smaller and therefore less fecund than a female of the same age in a warmer environment. On the other hand, life span in colder regions is longer and animals tend to grow larger (Allen 1959) making comparisons of upper limits of fecundity unsatisfactory unless size and age are considered as well.

A comparison of fecundity at length shows that Labrador shrimp produced fewer eggs per clutch than shrimp from the Gulf of Maine (Haynes and Wigley 1969). A 28 mm female produced around 2200 eggs in Hopedale and Hawke Channels and 2000 in the Cartwright Channel compared to 2800 in the Gulf of Maine. Mean water temperatures in the southern area during this time were about 5°C while those in Labrador averaged about 3°C. This is consistent with observations of increased fecundity with temperature. The Labrador data lie in an intermediate position between higher levels of fecundity observed

in the Gulf of St. Lawrence (warmer) and lower levels in the colder waters of St. Mary's Bay on the south coast of Newfoundland (G. E. Tucker, pers. comm.). Data for the Labrador area also suggested higher fecundity than the mean level of 1300 eggs given by Horsted and Smidt (1956) for areas off West Greenland. The temperature and fecundity relationships showed some inconsistency at extreme temperatures. Allen (1959) reported smaller shrimp and fewer eggs for P. borealis in the North Sea (where temperatures averaged 9°C) than in the comparatively colder (7°C) south Norway area. Ito (1976) indicated that shrimp in the sea of Japan lived at the extreme lower limit of the temperature range (0.4-0.8°C) but nevertheless females at comparable lengths carried approximately the same number of eggs as those observed in Labrador. In the colder waters off Japan the maximum size was greater and the number of eggs per clutch was as high as 4900. Presumably, growth and maturation were slower in the cold water and the shrimp ultimately obtained larger sizes due to increased longevity.

Although considerable data on fecundity were available for many stocks of P. borealis in the northern hemisphere, statistical comparisons were difficult to make since in many cases only ranges and means were provided and/or the data were not sufficiently detailed to construct and compare the log-log regressions.

Fecundity levels for females at comparable lengths were lower in the Cartwright Channel than either the Hawke or Hopedale Channels. Although bottom temperatures in these areas appeared similar, relatively low fecundity in the Cartwright Channel indicated that water temperature in this area might have been slightly colder than in the other two areas where shrimp were abundant. This conclusion

is supported by temperature data collected in the areas (see Distribution). Therefore, interpretation of fecundity data, either in terms of productivity or environmental trend, should be made on a per channel basis.

Food and Feeding

Results of the present study were used to interpret some of the more general food and feeding habits of P. borealis off coastal Labrador. Diet appeared to be varied in samples examined from the Hawke and Hopedale Channels. Most contents were not identified. Considering the small size of the shrimp and the grinding action of the mandibles during feeding, particle size in relation to size of food organisms was small. Therefore, identification was not easily accomplished in a general food and feeding study.

Crustacea were identified most frequently among the stomach contents, suggesting the potential for active predation, scavenging, and/or cannibalism. If some of the crustacea which serve as food for shrimp were partially or wholly pelagic (such as copepods and euphausiids observed by Squires (1970) in shrimp off Labrador) then the possibility for vertical movements and/or migration also exists. Other material identified as sand or mud, polychaetes, detritus, and phytobenthos[6] indicated benthic feeding and scavenging.

Data were inadequate to determine differences in diet between and within areas and years or at different times during the 24-hour cycle. Qualitative observations suggested differences in feeding intensity between the two areas surveyed. Since samples from the Hawke Channel (1973-77) and the Hopedale Channel (1977-78) were

[6]Squires (1970) defined phytobenthos as 'greenish material with some diatoms, filamentous algae or dinoflagellates'.

taken in different years, this might account for the overall variability between samples reported in the present study.

More detailed examination of one sample from the Hopedale Channel showed differences in feeding by sex and maturity stages. Incidence of food in the stomachs of male shrimp was higher than that of females. A corollary to this observation was that the smaller shrimp might have been more actively feeding than the larger animals. This is supported by data cited previously which suggested greater vertical movement (to feed) for smaller shrimp (see Distribution). Ovigerous females, although restricted in their movements by the attachment of eggs to the pleopods, fed more intensively than non-ovigerous females. The latter showed the highest incidence of empty stomachs. This lack of feeding activity may be associated with onset of oviposition or the preceding molt since during this time of year (August) eggs are usually extruded. Similar observations were made by Weinberg (1980) on P. borealis in the North Sea.

Results of this study were consistent with those reported by Squires (1970) in northern waters in terms of food items and high incidence of empty stomachs (50-70%). Food and feeding studies for P. borealis and pandalids, generally, in other areas also supported present observations of variable diet and feeding strategies. Fox (1972) summarized pandalid food and feeding in various locations, indicating scavenging, cannibalism, and bottom and pelagic carnivorous activity. Horsted and Smidt (1956) concluded that bottom feeding was supplemented by pelagic activity, especially at night, in pursuit of pelagic crustacea. A description of diel vertical migration of P. borealis in Alaska was given by Barr (1970) who

also determined that the species in the Kachamak Bay area were primarily zooplankton feeders and fed heavily at night.

On the other hand, Rice et al. (1980) showed that three pandalids (including P. borealis) from Cook Inlet, Alaska, fed predominantly on benthos and not in the water column.

Apollonio and Dunton (1969) showed seasonal shifts in diet between benthic and pelagic feeding in the Gulf of Maine and credited most of the change to feeding activity of females. Weinberg (1980) found that shrimp in the North Sea generally fed more heavily during midday and less extensively during early morning and late evening. In this case the heavy feeding could have been associated with the time spent on or close to the bottom with periods of decreased activity occurring during vertical migration.

Most studies on food and feeding of P. borealis have tended to group food items in general taxonomic categories because of the difficulty of identifying small pieces of macerated organisms. The recent study by Rice et al. (1980), however, introduced identification at the generic level and resulted in a total of 28 food categories. Weinberg (1980) identified 158 species and higher taxa from grab samples of substrate from Fladen Ground and Farn Deeps (North Sea), and an additional 9 species or congenerics from shrimp stomachs which were not found in grab samples.

Qualitatively, food and feeding patterns for shrimp in areas off Labrador were similar to conspecifics in other areas. Results from the present study suggested a potential for both bottom and pelagic feeding but data were insufficient to conduct detailed analyses.

A more detailed study involving a systematic collection of samples and identification of stomach contents to species where possible is recommended to determine differences within and between areas and years, between sexes and within apparent diel rhythms.

Parasites of Shrimp Eggs

Apollonio and Dunton (1969) described the occurrence of non-viable eggs from P. borealis in the Gulf of Maine and suggested that non-viability resulted from shrimp encountering relatively warm water. Associated with the non-viable eggs was infestation of the egg-mass with "an unidentified stalked protozoan". Upon shedding of the eggs many of these protozoans could be seen attached to the pleopods.

Haynes and Wigley (1969) also noted the occurrence of non-viable eggs from P. borealis in the Gulf of Maine which were recognized by their greater size, irregular outline and whitish colour.

Stickney (1978) found parasites within the eggs. These parasites showed affinities with a group of parasitic dinoflagellates (suborder Peridiniina) and appeared in four forms. An apparently greater fecundity of shrimp in the Gulf of Maine in the 1978-79 season may have been partly due to a decrease in the incidence of this parasite (Stickney and Perkins 1979). Similar parasites have been observed in shrimp eggs from the Gulf of Alaska and in pandalid species other than P. borealis (Stickney 1981).

The parasite observed in the samples from the Cartwright Channel compares in general description with that observed by Stickney in the Gulf of Maine. The larger 'spores' are analogous

to Form 3 of Stickney and the smaller may be representative of Form 4. Under methods of preservation and staining used here, no flagella could be observed in either form. Material analagous to Stickney's Forms 1 (cysts) and 2 (plasmodia) could not be detected with any certainty.

In one sample (No. 34, Appendix III) some of the non-viable eggs were only partially white and some of these white areas formed a 'Y' configuration. It was initially thought that this area might have represented the embryo and served as the focus of infection which, in turn, spread to fill the egg capsule. However, under the microscope these eggs appeared to contain only material similar to that found in healthy eggs and no parasitic forms were observed. In the Gulf of Maine, Stickney has observed fresh material and followed the development of plasmodia (Form 2) which eventually fragmented into motile, flagellated cells or 'spores' (Forms 3 and 4). From his observations, once an embryo was formed there was no infection (pers. comm.).

Infection of shrimp eggs with an apparent parasitic dinoflagellate occurred in the Cartwright Channel in 1979 accounting for varying proportions of non-viable eggs in the clutch. Because these non-viable eggs were seen in the other shrimp channels and in different years, it can be assumed that the conditions existed previously in the area. Proportions of non-viable eggs were similar to those observed in the Gulf of Maine. In the latter area, it was observed that there appeared to be a positive relationship between temperature and non-viable egg production. However, data from Labrador comparing percent non-viable eggs and temperature were lacking. Bottom

temperatures in the Labrador Channels were relatively constant throughout the year, usually between 2 and 4°C. In the Gulf of Maine autumn inshore temperatures can exceed 5°C. Therefore, development of the parasites in the colder area probably takes considerably longer than in the warmer area (Stickney 1978).

Comparisons of fecundity in areas where such infections occur must be made with caution. Samples should be taken early in the ovigerous period to avoid bias caused by incidental egg loss and mortality. Also accurate records of incidence of non-viable eggs must be maintained to evaluate effective fecundity. For example, the number of eggs produced per female in the Cartwright Channel may be less than that produced in the other channels but this may not be a fair comparison unless the numbers of viable eggs (effective fecundity) are considered as well.

There was also considerable variation in the proportions of non-viable eggs and percent infected from individuals taken in the Cartwright Channel. The condition (or conditions) represented a potential for considerable egg loss and spawning failure relative to average production. Therefore, it is recommended that further studies be undertaken to: a) identify the parasite; b) determine the life cycle; c) determine infection rates between years and areas; and, d) relate results of c) to abundance and/or relative year-class strength.

Muscle Necrosis

Butler (1980) reported a similar muscle condition in Pandalus jordani, a species of commercial importance off British Columbia.

Prevalence in that area was also low (less than 1%) and was not considered an important factor in shrimp mortality. The etiological agent was identified as a new species of microsporidia, Thelohania butleri (Johnston et al. 1978). Various stages of this parasite were described in detail through light and electron microscopy. Ovoid spores approximately 4.8 X 3.1 µm were found which were considerably larger than either of the spore types shown in Fig. 25.

Microsporidiosis has also been reported in penaeid shrimp from the Gulf of Mexico (Iversen 1969, Johnson 1978). Thelohania, Pleistophora, and Nosema have been identified as genera involved in what fishermen in that area refer to as 'milk' or 'cotton' shrimp. The symptoms were similar to the opaque muscle condition noted in the present study.

Kelly (1979) observed tissue specificity in three microsporidian parasites of the pink shrimp, Penaeus duorarum. These were Thelohania duorara, Agmasoma penaei, and Pleistophora sp. The former and latter produced conditions in muscle tissue similar to that observed from shrimp from the Labrador Sea. Thelohania duorara infections were widely spread between muscle fibres where lysis was minimal. Pleistophora sp., on the other hand, only infected a small portion of muscle fibres within muscle fascicles. Muscle atrophy was mainly associated with infections of this type.

Spontaneous muscle necrosis has also been observed in brown shrimp, Penaeus aztecus (Rigdon and Baxter 1970). The condition was characterized by focal irregular white areas in the muscle surrounded by normal muscle tissue. Bacteria, as a secondary infection, was found only rarely and no parasitic organisms were

observed. Physiological stress due to environmental perturbation appeared to be the cause of the necrosis.

Conditions very similar to those found in shrimp off Labrador in the present study have been credited to infections with microsporidia of the genera Nosema, Thelohania, and Pleistophora. Tissue specificity and general infection characteristics indicated that the condition described for shrimp off Labrador was similar to symptoms associated with the latter. Characteristics were similar in that nearly all striated muscle contained spores. The heaviest infections occurred near the periphery of muscle bundles, interstices were not heavily infected and whdle muscles or muscle fascicles were never completely destroyed. Differences included evidence of heavier infections off Labrador and no noticeable infiltration of muscles with connective tissue.

Although spores were not characteristically found between muscle fibres, serious consideration must also be given to the description of infection of P. jordani with Thelohania butleri. Manifestations of the conditions were similar to those in P. borealis off Labrador and the hosts are closely related, taxonomically. Despite the fact that spores for T. butleri were larger than both types observed in this study, the genus is often characterized by having spores of two sizes - macrospores and microspores (Manwell 1968) and different species show a range of spore sizes (Kudo 1954) similar to those observed in the present study.

Johnson (1978) distinguished the genus Nosema from Thelohania and Pleistophora by the absence in the former of 'an enclosing membrane' around the spores. No such membranes were evident in the Labrador specimens at that stage of infection. Sprague (1970)

distinguished the three genera through characteristics of spore production. Nosema produces only one spore per sporont, Thelohania, eight spores per sporont and Pleistophora, sixteen or more spores per sporont.

Animals caught with opaque musculature did not appear to function differently from other 'healthy' animals in the catch. If this is true in situ then considerable muscular function must be maintained and the low prevalence of the extensive infections observed may be representative of the population assuming the diseased animals are equally available to the sampling gear. Therefore, the contribution to the total mortality of P. borealis in these areas could be minimal. However, only animals with obvious infections have been examined. No examination of apparently 'healthy' animals has been made to determine prevalence of less severe infections.

The lack of noticeable behavioural differences was also noted in Penaeus duorarum infected with Pleistophora sp. (Kelly 1979). Johnson (1978) reported that although infected shrimp were agile and fed 'normally', reproduction might have been adversely affected. No evidence to the contrary was available from Labrador, but it is important to note that infection was observed in animals which were transitional between male and female sexes. Whether or not infection was initiated before or after the onset of sex reversal is unknown.

Spontaneous muscle necrosis must be ruled out in these instances since there is evidence of a possible etiological agent. In addition, shrimp which experienced this necrosis had a marked diminution of body movements and some died within 18-24 hours (Rigdon and Baxter 1970). Secondary infection with bacteria, observed in one specimen by

these authors, was not observed in the samples from Labrador.

Pandalus borealis is a protandric hermaphrodite and sexual condition is representative of both size and age. Spores of microsporidia have been found in both sexes and in transitional stages and it can be concluded that, for the animals observed, there was no apparent relationship between the infection and either length or age. A larger sample size is necessary to determine this relationship and define any possible thresholds.

Although prevalence of this condition was low, experience with concentrations of shrimp extending from as far south as the Northeast Newfoundland Shelf north to the Davis Strait has suggested that it generally increased with latitude. Consideration should be given to the use of this condition as a potential biological tag which may be useful in studies of stock discrimination.

Finally, microsporidian spores have been found in association with the condition of opaque musculature. To this point it has not been shown that the condition is caused by the presence of the parasite. Identification of the microsporidian was not possible since only spores were observed. The pattern of spore production by sporonts is necessary to determine the correct genus. Possibly, the parasite is Thelohania butleri since it has been reported previously in the same host genus. Additional work is necessary in both etiology and taxonomy.

SUMMARY

1. Shrimp in the Labrador Channels were concentrated in water between 2 and 4°C in depths greater than 300 m. Hopedale and Hawke Channels generally showed localized areas of concentration within channels with lower abundance elsewhere, while the Cartwright Channel did not exhibit this pattern.

2. Variability between years indicated that these stocks are capable of considerable movement, presumably within environmental limits such as temperature and substrate.

3. Decreases in density and abundance were apparent from research survey catch data from the Hopedale and Hawke Channels. The decreases in the former area might have been a function of increased mortality through fishing, increased abundance of a predator (Greenland halibut) and/or changes in patterns of seasonal availability but were attributed solely to natural causes in the latter. Changes in density distribution were noted for Cartwright Channel between years from 1979 to 1981 but there was little indication of changes in relative abundance.

4. Generally, shrimp in these areas showed an increase in size with depth, the deeper strata often containing mostly large female shrimp. Distribution of this type reduces the effects of mortality through fishing on the younger animals since larger shrimp (especially females) are preferred by the industry.

Research fishing stratified by depth should be continued to monitor changes in this pattern within and between years.

5. Shrimp catches off Labrador have been shown to vary considerably over a 24-hour period with lowest levels occurring during the night. Catches during hours of daylight were themselves variable as were the times of highest catches.

6. Diel vertical migration was interpreted from changes in average size in the catch over a 24-hour period but was not considered to be the sole source of variation in the catch data. Semi-diel rythms such as tidal currents were discussed as a possible contribution to the variability problem.

7. Protandry appeared to be obligatory in shrimp off Labrador with no evidence of early-maturing females. Transitionals occurred in large numbers in a July, 1980 survey and probably belonged to the same year-class as first-year females since modal lengths of both groups were similar and most animals would have spawned in that year.

8. Females spawned in successive years for at least two years and likely more. A small proportion of females (presumably from a number of year-classes) did not spawn in 1980. This has been shown to have happened in other years as well and probably was related to relatively low water temperatures present in these areas.

9. Differences observed in size at sex change between areas may represent different stock characteristics. Differences between years may have been partly due to by changes in the environment (eg. temperature) or sampling errors but may also have represented the effects of a fishery primarily aimed at larger females.

10. Weight-length relationships for shrimp in the Labrador Channels were themselves similar and similar to those reported for the same species in other parts of the northern hemisphere. Statistically significant differences were obtained between channels, however, and individual equations should be used in calculating such values as yield per recruit.

11. Fecundity of shrimp in these areas lies within a range exhibited for conspecifics in other areas. Number of eggs per clutch appeared to be lower than in warmer regions such as the Gulfs of St. Lawrence and Maine but higher than in some colder areas off West Greenland and in some Newfoundland bays. Inconsistencies in this pattern at the extremes of the range of temperature tolerance also were evident.

12. Fecundity was less in the Cartwright Channel than in the other two areas which might be due to slightly colder water in the former. Interpretations of fecundity in terms of productivity or as an environmental indicator should be made for channels separately.

13. Food and feeding patterns were generally similar to those of other northern shrimp stocks which showed both bottom and pelagic activity. Males appeared to be more actively feeding than females and ovigerous females more actively feeding than non-ovigerous females. A more detailed study is recommended.

14. Shrimp eggs were infected with what appeared to be a parasitic dinoflagellate described previously in the Gulf of Maine. The condition represented a potential for considerable egg mortality and spawning failure. Therefore, additional studies were recommended.

15. A small proportion of shrimp off Labrador were extensively infected with a microsporidian which possessed characteristics similar to the genera Nosema, Thelohania, and Pleistophora. Infection did not appear to be size related. More detailed studies should be carried out in etiology and taxonomy and the parasite's potential as a biological tag should be investigated. Thelohania butleri was reported from Pandalus jordani in the Pacific and could possibly be the parasite observed in the present study.

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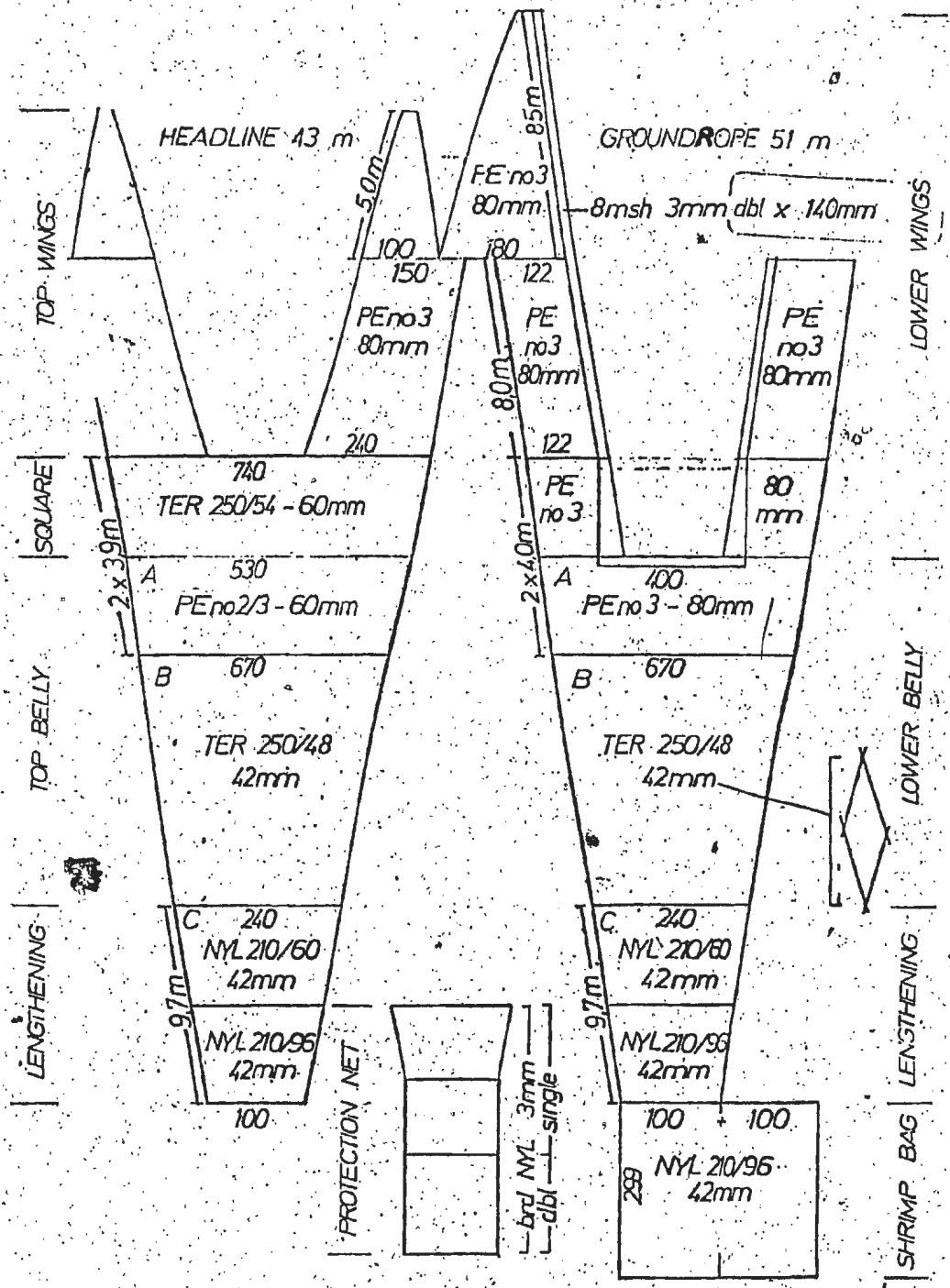
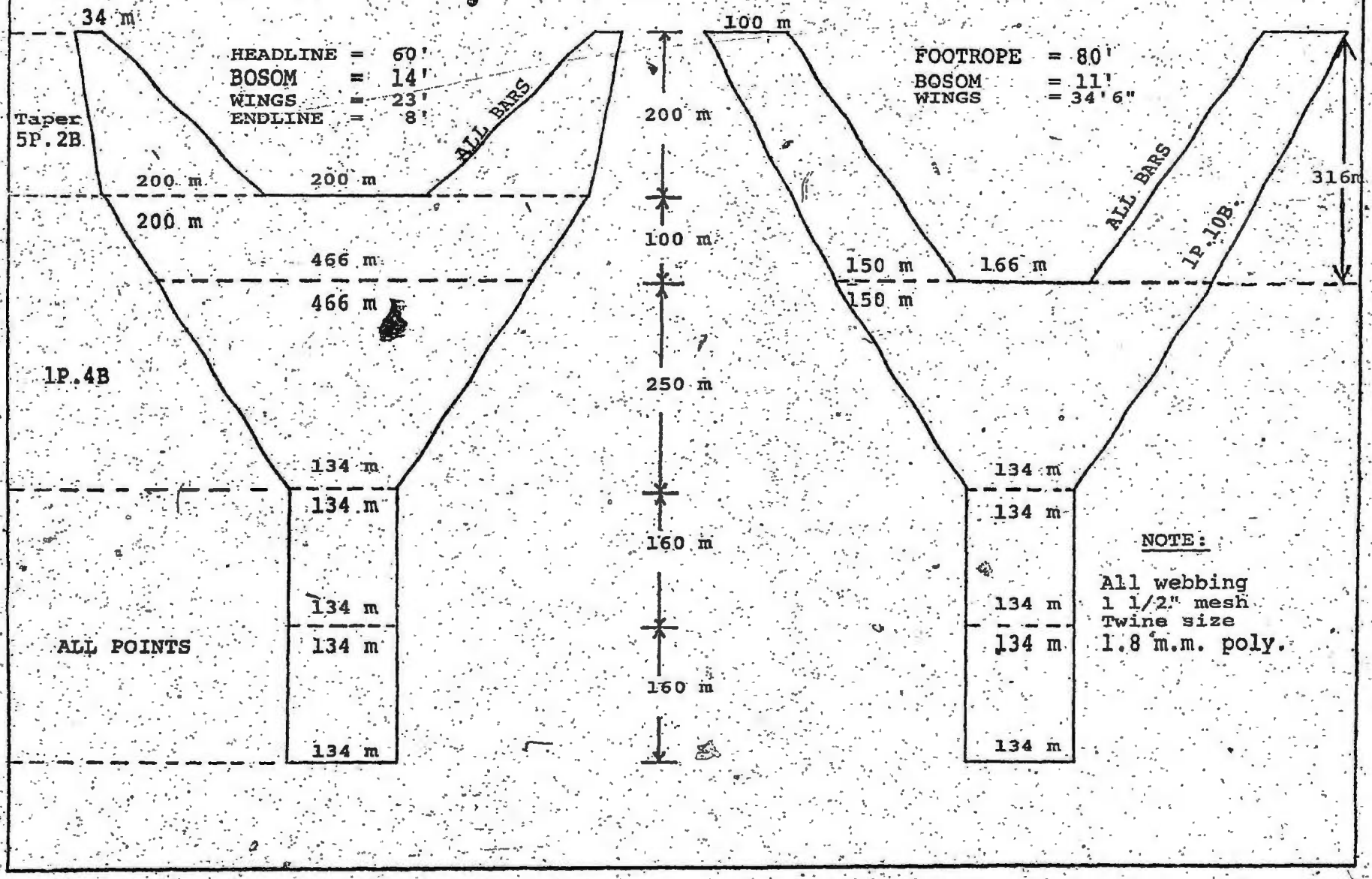
Appendix I

SPUTNIK TRAWL 1600



Appendix II

NO. 36 YANKEE SHRIMP TRAWL



Appendix III. Details of egg samples - Cartwright Channel - 1979.

No.	Carapace length (mm)	Total no. eggs	No. eggs viable	No. eggs non-viable	% non-viable	Subsample non-viable	No. infected	% infected	Notes
1	27.9	1901	1687	214	11.26	63	24	38.10	7[a]
2	24.3	1373	1243	130	9.47	20	0	00.00	1[a]
3	27.1	1789	1774	15	0.84	10	0	00.00	1[b]
4	29.3	2366	2302	64	2.70	10	1	10.00	
5	25.7	1287	1272	15	1.17	10	2	20.00	1[b]
6	22.5	1081	1002	79	7.31	10	2	20.00	1[a]
7	22.7	836	822	14	1.67	10	3	30.00	
8	23.4	794	766	28	3.53	10	1	10.00	3[a]
9	23.7	1117	1087	30	2.69	10	1	10.00	
10	26.7	1439	1398	41	2.85	10	1	10.00	1[a]
11	26.9	1540	1439	101	6.56	10	0	00.00	1[a]
12	25.1	1511	1490	21	1.39	10	2	20.00	
13	24.8	1215	1129	86	7.08	10	0	00.00	2[a]
14	26.2	1182	1089	93	7.87	10	4	40.00	1[a]
15	23.9	1241	1203	38	3.06	10	1	10.00	
16	25.0	1427	1464	63	4.41	10	0	00.00	1[a]
17	26.4	1364	1311	53	3.89	10	1	10.00	2[a] 2[b]
18	28.1	1871	1844	27	1.44	10	2	20.00	1[a] 1[b]
19	25.7	1436	1317	119	8.29	10	0	00.00	
20	23.2	1026	1005	21	2.05	10	1	10.00	
21	22.8	1116	1106	10	0.90	10	1	10.00	
22	25.3	1335	1295	40	3.00	11	4	36.36	
23	27.4	1923	1859	64	3.33	10	2	20.00	
24	22.8	948	903	45	4.75	10	0	00.00	1[a]
25	24.8	1525	1454	71	4.66	10	2	20.00	
26	28.1	1547	1430	117	7.56	10	1	10.00	
27	27.2	1426	1377	49	3.44	10	5	50.00	
28	28.2	1985	1959	26	1.31	10	1	10.00	
29	25.8	1739	1539	200	11.50	10	1	10.00	
30	29.1	1775	1580	195	10.99	10	6	60.00	
31	24.4	1308	1246	62	4.74	10	6	60.00	
32	24.6	1547	1529	18	1.16	10	1	10.00	
33	23.6	1349	1285	64	4.74	10	1	10.00	1[a] 1[c]
34	27.0	1697	1460	237	13.97	10	1	10.00	2[c] 3[d]
35	26.0	1406	1318	88	6.26	10	4	40.00	3[a] (obvious)
36	27.6	1694	1364	330	19.48	10	3	30.00	
37	25.4	1319	1287	32	2.43	10	5	50.00	
38	25.2	1276	966	310	24.29	10	5	50.00	1[b]
39	24.1	1332	1173	159	11.94	10	7	70.00	
40	28.8	1738	1661	77	4.43	10	2	20.00	2[a] (obvious)
41	23.2	1332	1177	155	11.64	10	5	50.00	
42	23.9			72		10	3	30.00	viable egg sample lost
43	24.0	1097	1061	36	3.28	10	2	20.00	
44	27.0	1546	1540	6	0.39	6	2	33.33	1[a]
45	28.8	2178	1990	188	8.63	10	0	00.00	1[a] (obvious)
46	25.4	1407	1389	18	1.28	10	1	10.00	
47	23.5	1240	1216	24	1.94	10	4	40.00	
48	24.2	1043	1013	30	2.88	10	1	10.00	

[a] = evidence of small spores not included in infection rates.

[b] = infection doubtful - not included in infection rates.

[c] = structurally healthy.

[d] = structurally healthy and partially white.

APPENDIX IV

Preparation of tissues for electron microscopy

1. Sea water Karnovsky fixative

paraformaldehyde	2 gm
filtered sea water	25 ml
IN sodium hydroxide	3 drops
50% glutaraldehyde	5 ml

Sorenson's buffer (p H 7.2)

Sorenson's buffer was added to bring the total volume to 50 ml and a pH of 7.0. The solution was kept cold.

2. 2% osmium tetroxide

The fixative was prepared by first dissolving the osmium tetroxide crystals in 2 ml of distilled water and adding Sorenson's buffer (pH 7.2).

3. Fixation

The tissues were fixed equal volumes of sea water Karnovsky and osmium tetroxide simultaneously kept cold for one hour, washed thrice in cold buffer and dehydrated in a graded series of alcohols. Spurr's was used as the embedding medium.